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Microwaves&RF®

RF, COMMUNICATIONS, AND MICROWAVE TECHNOLOGY AND NEW-PRODUCT COVERAGE—IN DEPTH AND IN CONTEXT

MARCH 2022 mwrf.com

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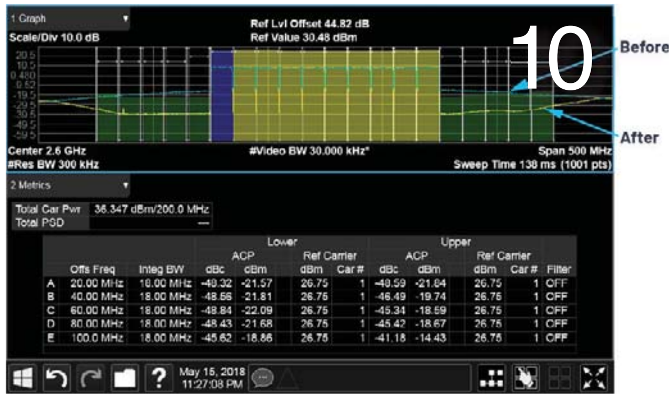

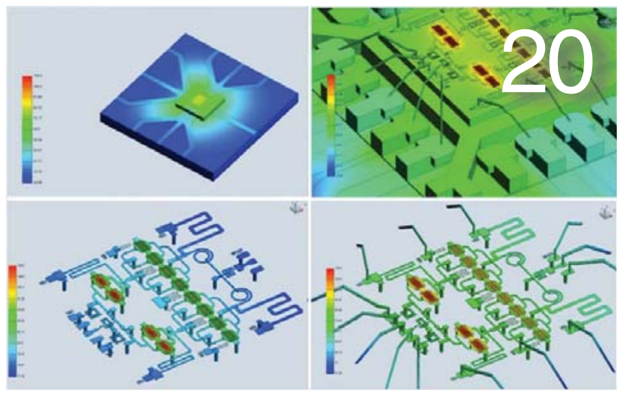

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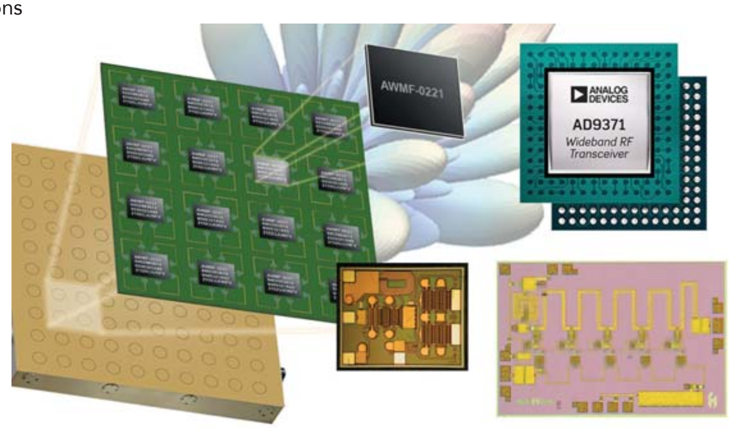

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Editorial

DAVID MALINIAK | Editor

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Having Passed a Milestone, We're Taking a New Tack

Sometimes milestones give one pause to reconsider the mission at hand and how to enhance it.

In November, *Microwaves & RF* marked its 60th anniversary of serving the community of high-frequency design engineers. Concurrently, we've been pondering our mission and how best to move forward into the future. We've thought over our approach up to this point and how we can better service our audience.

Throughout its history, *Microwaves & RF* has been the industry's go-to source for the latest in technology, trends, and news. It's also where engineers turn for the latest developments in new products for their design projects.

As it enters its next 60 years, we at *Microwaves & RF* will be the RF/microwave engineer's critical source for new product and technology information for communications/wireless-related designs. From 5G/6G to IoT/IIoT, military/aerospace to ISM, EMC/EMI to test and measurement, and geolocation services to broadband—if RF/microwave design projects need it, we cover it, in depth and in context.

One perennial issue gleaned from our Salary Surveys is that engineers don't have enough time to get their jobs done. Thus, we're increasing our value to our audience by reshaping how we present information. We're taking care to structure technology content in a scannable, sectioned form that takes the reader from general information at the outset (The Overview), to application context (Who Needs It and Why?), to deep technical insights (Under the Hood). We compile relevant content into meaningful presentations for a truly optimized information collection.

When it comes to our website (*www.mwrf.com*), we've implemented an AI interface that can recommend supplementary content, eBooks, and other materials to further personalize a user's experience. And that's not the only way in which we've enhanced our website—new and growing video initiatives such as our TechXchange Talks, QuickTalks, and editorial webinars will let you hear directly from industry leaders with fresh insights into the directions technology is taking.

Many publications have what's known as a "tagline," a slogan of sorts that encapsulates what the publication is about. Some are famous, such as the *New York Times*'s "All the News That's Fit to Print."

We've changed our tagline to reflect these enhancements to our mission. It's what we do here at *Microwaves & RF*: "RF, Communications, and Microwave Technology and New-Product Coverage—In Depth and In Context." By hewing closely to our tagline, we'll remain your go-to source for the latest in technology, trends, and news about the RF/microwave industry. mw

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SDLVAC-0120-70M


SDLVA-100M4G-CD-2


SDLVA-100M20G-55-12-SFF
SDLVA-1G20G-55-12-SFF
SDLVA-1G20G-58-12-SFF


SDLVA-0R71R3-75-MEC
SDLVA-2G6G-70-CD-1


SDLVA-07103-70-LA3

PMI Model No.	Frequency Range (GHz)	TSS (dBm)	Log Slope (mV/dB)	Log Linearity (dB)	Dynamic Range Log (dBm)	Size (Inches) Connectors
SDLVAC-0120-70M	0.1 - 2	-65 Min -70 Typ	30 Typ 100 Ω Load	±1.5 Max	-65 to +5	Surface Mount 0.395" x 0.28" x 0.09" leads 0.24" min
SDLVA-100M4G-CD-2	0.1 - 4	-73 Typ -71 Min	25 Typ 50 Ω Load	±2.5	-70 to 0	3.2" x 1.8" x 0.4" Removable SMA (F)
SDLVA-100M20G-55-12-SFF	0.1 - 20	-55 Typ	15 Typ 1k Ω Load	±1.5 Typ	-50 to +5	PE2 Housing 1.08" x 0.71" x 0,29" Removable SMA (F)
SDLVA-0R71R3-75-MEC	0.7- 1.3	-70 Typ	40 Nom ±1 mV Typ 50 Ω Load	±1.5 Max ±1.2 Typ	-65 to +5	3.75" x 1.5" x 0.5" SMA (F)
SDLVA-07103-70-LA3	0.75- 1.25	-70 Max	30 ± 5% 100 Ω Load	±1.5 Max	-65 to +5	1.3" x 0.95" x 0.27" Removable GPO (Full Detent)
SDLVA-1G20G-55-12-SFF SDLVA-1G20G-58-12-SFF	1 - 20	-58 Typ -60 Typ	50 Typ 50 Ω Load 14 Typ 1k Ω Load	±1.5 Typ ±1.0 Typ	-55 to +5 -54 to +5	PE2 Housing 1.08" x 0.71" x 0,29" Removable SMA (F)
SDLVA-2G6G-70-CD-1	2 - 6	-70	40 Nom 50 Ω ± 10%	±1.75 Max	-65 to +5	3.75" x 1.5" x 0.5" Removable SMA (F)
SDLVA-218-65-16MV-12DBM SDLVA-218-75-16MV-12DBM	2 - 18	-64	16 ± 2 Nom 50 Ω Load	±2.2 Typ ±2.5 Max	-55 to +10 -60 to +15	4.24" x 0.994" x 0.38" Removable SMA (F)
SDLVA-6G18G-CD-2-OPT218	2 - 18	-70 Min	25 ± 10% 50 Ω Load	±2.5	-70 to +5	3.2" x 1.8" x 0.4" Removable SMA (F)
SDLVA-6G18G-CD-2	6 - 18	-70 Min	25 ± 10% 50 Ohms 48 ± 10% No Load	±2.5	-70 to +5	3.2" x 1.8" x 0.4" Removable SMA (F)
PLVA-6G18G-40-1	6 - 18	-42	50 ± 4% 50 Ω Load	±1.0 Max	-40 to 0	2.2" x 1.5" x 0.4" Removable SMA (F)
DLVA-18G40G-42-50-CD-1	18 - 40	-34	50 ± 3 dB 100 Ω load	±0.5	-32 to +10	1.86" x 1.69" x 0.40" 2.92mm (F)
SDLVA-18G40G-65-CD-292FF	18 - 40	-65	25 Nom 50 Ω Load	±2.0 @ 25 °C, ±3.0 over temp	-63 to +2	2.37" x 1.8" x 0.42" Removable 2.92mm (F)


SDLVA-218-65-16MV-12DBM
SDLVA-218-75-16MV-12DBM


SDLVA-6G18G-CD-2
SDLVA-6G18G-CD-2-OPT218


PLVA-6G18G-40-1


DLVA-18G40G-42-50-CD-1


SDLVA-18G40G-65-CD-292FF

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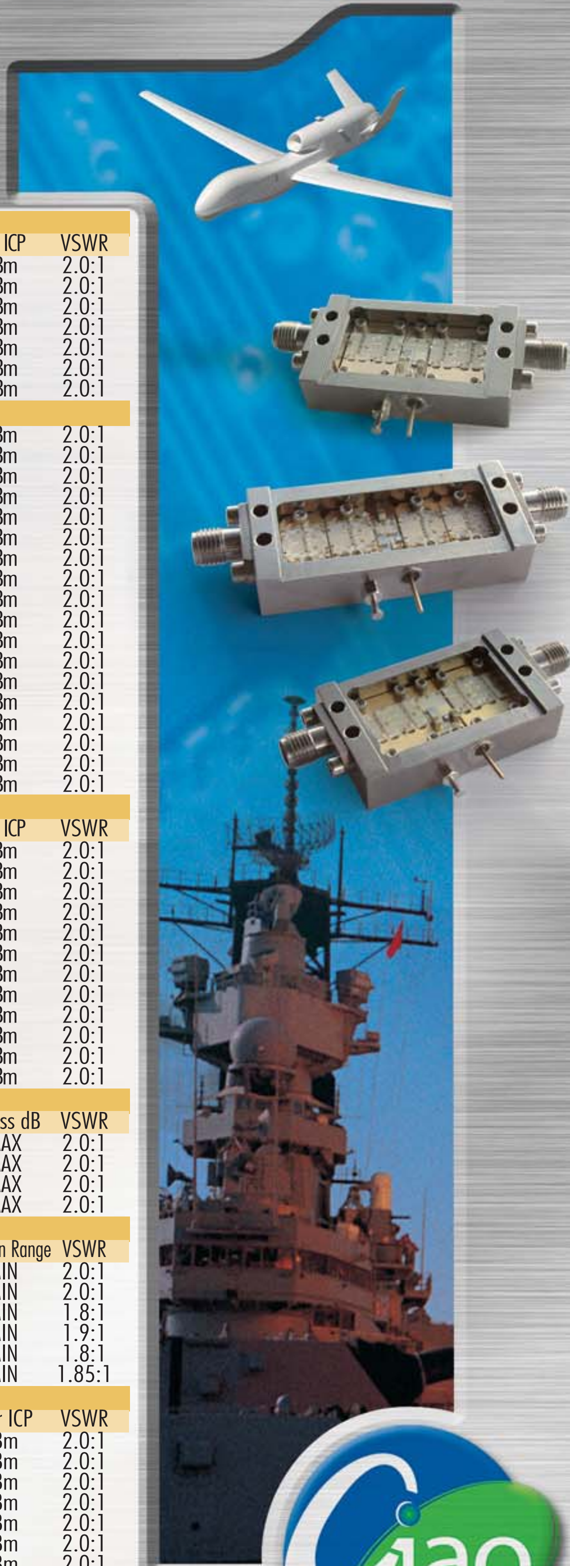

OCTAVE BAND LOW NOISE AMPLIFIERS

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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News

Featured New Product

Benetel's Outdoor 5G OpenRAN RUs Target Private and Public Networks

The Overview

Benetel

To bring 5G capacity to private, campus, and industrial networks as well as rural networks and public hotspots, Benetel has expanded its range of radio units (RUs) through the introduction of the RAN650. This latest RU is intended to bring 5G capacity to private, campus and industrial networks, as well as rural networks and public hotspots.

Who Needs It and Why?

In Benetel's reckoning, a broad array of verticals is addressable with the RAN650 O-RU. They'll be applicable in some countries that are opening new spectrum for 5G private networks in industrial, campus, or smart city use cases. The latter is an exercise in building a base infrastructure, and of municipal authorities examining how citizens will use it and how to leverage the infrastructure in novel ways. With regard to 5G hotspots on campuses in various venues, both Benetel's earlier RAN550 indoor O-RUs and the new outdoor O-RUs are applicable. For rural broadband, the RAN650 O-RU represents an opportunity to bring high-speed internet into rural areas.

Under the Hood

In the RAN650 O-RU, a 4T4R antenna arrangement is featured with up to 5 W of output power being delivered per antenna port (equating to 20 W in total). The 7.2x functional split employed will help minimize the costs associated with radio access network implementations, while support for 100 MHz of instantaneous bandwidth will enable maximum coverage to be attained.

The O-RU can be deployed in either a Cat A- or Cat-B-based configuration (using selected distributed units), thereby providing flexibility to address radio access network architectures. To attain to its high performance levels and versatility, each RU incorporates an Intel Arria 10 FPGA alongside an Analog Devices' ADRV9029 4T4R transceiver with integrated digital predistortion (DPD). The initial version of the RAN650 covers the n77u (3.7 to 4.2 GHz) frequency range. An n78 variant (3.3 to 3.8 GHz) will be made available in the second quarter of 2022.

The RAN650 RU runs off a 48-V supply and has typical power consumption of 100 W. Its robust IP65-rated enclosure withstands extremely challenging outdoor conditions. The unit supports an operational temperature range from -33°C to +45°C.

The RAN650 complements Benetel's existing OpenRAN portfolio, which includes the RAN550 indoor 5G RU that the company announced back in late 2020. Active network trials are already being conducted on the Benetel RAN650 by a handful of pilot customers. ■

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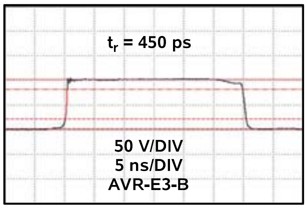
AVOZ-D6-B: 1000V / 200A, 1-10 us pulser

AV-1010-B: General purpose 100V, 1 MHz pulser

AVO-9A-B: 200 ps t_r, 200 mA laser diode driver

AV-156F-B: 10 Amp current pulser for airbag initiator tests



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50 V	500 ps	1 MHz	AVR-E5-B
100 V	500 ps	100 kHz	AVR-E3-B
100 V	300 ps	20 kHz	AVI-V-HV2A-B
200 V	1 ns	50 kHz	AVIR-1-B
200 V	2 ns	20 kHz	AVIR-4D-B
400 V	2.5 ns	2 kHz	AVL-5-B-TR

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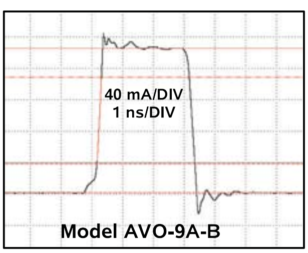

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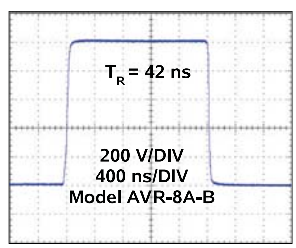

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Collaboration to Improve 5G mmWave Cellular Coverage

LITEPOINT ANNOUNCED A TECHNOLOGY development partnership with Sivers for its 5G mmWave Antenna-in-Package (AiP) products. The fully integrated IQgig-5G is a versatile multiband mmWave non-signaling test solution presented as the first of its kind to support all 5G FR2 frequencies within the 23- to 45-GHz frequency range. All signal generation, analysis, processing, and RF front-end switching are self-contained inside a single chassis. The test system enables small-cell waveform generation and analysis for 5G radio technologies and allows for real-time RF parametric analysis for small-cell products.

Sivers's ECLIPSE3741 is a highly integrated 5G beamformer phased-array Antenna in Package (AiP) module. It combines multiple Sivers RFSOI beamforming front-end integrated circuits with a 16-element (4x4) antenna array. Covering FR2 band, n260 from 37.0 to 41.0 GHz, it offers exceptionally high linear output power, efficiency, and extreme integration. This AiP module is designed to enable λ/2 wavelength antenna lattice spacing when tiled together to support higher-power applications. It also has been extensively optimized for heat management. ■

60-GHz CMOS Radio
Chip and Phased Antenna Array Streamlines 5G Deployments

PHARROWTECH LAUNCHED THE PTR1060, presented as the first IEEE 802.11ay-compliant CMOS RF chip for indoor and outdoor wireless use cases that supports the full 57- to 71-GHz bandwidth. Addressing Fixed Wireless Access (FWA) deployments, 5G and Wi-Fi infrastructure backhauling, and next-gen IoT devices, the solution streamlines the design process and reduces total system cost, with an MCU allowing on-chip calibration and customization for specific apps.

The PTM1060 (RFM) phased-array antenna module includes the PTR1060, and when combined with Renesas' RWM6050 baseband, offers ODM/OEMs a ready-to-use 60-GHz solution, with the ability to customize the RFM to custom specifications. The RFIC boasts 32 antenna paths with an on-chip TRX switch, significantly reducing the antenna footprint and resulting in lower-cost RF antenna modules. The chip also has an 802.11ay-compliant RF with channel bonding and six full channels between 57 to 71 GHz, and a low-noise synthesizer to enable up to 64 QAM modulation. ■

STEVE SUMMERFIELD | Director Algorithm Implementation, Analog Devices
FRANK KEARNEY | Director of Systems Architecture, Analog Devices

How to Make a Digital Predistortion Solution Practical and Relevant

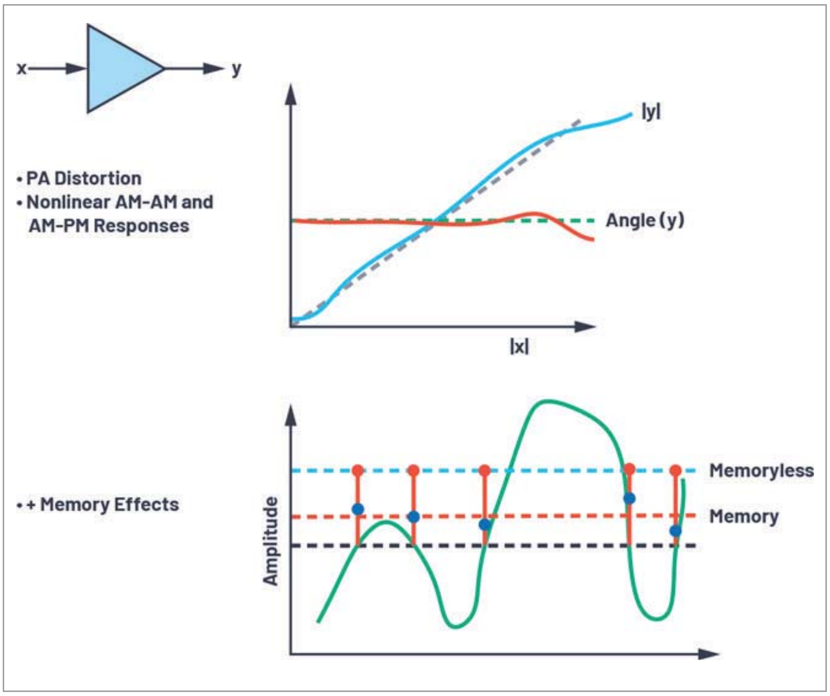
For digital predistortion implementations, static quantitative data fails to capture many challenges, risks, and performance tradeoffs of real-world scenarios. Here's how to get beyond fundamentals and into considerations for complex 5G environments.

In an ideal world, the output of a power amplifier (PA) would be an identical scaled version of the input and most of the power consumed by the amplifier would reside in the output signal. Hence, we would have maximum efficiency and no distortion. In the real world, though, we fall short—real linear amplifiers tend to have very poor efficiencies.

Amplifiers used in cable distribution systems, for example, have excellent linearity, but this comes at the cost of efficiency. In most cases, the efficiency struggles to achieve greater than 6% with the balance of the power (94%) being wasted, which imposes economic, environmental, and application costs. In cellular base stations, electricity accounts for over 50% of the operating-expense (OPEX) costs.

Wasted power increases electricity usage and produces greenhouse gases, while much of the power that isn't emitted as radio waves must be dissipated as heat. Consequently, active and passive thermal management is needed.

Over the last several decades, the cellular industry has pushed the efficiency of the PA to a performance level of more than 50%. This has been achieved by adopting smart architectures such as the Doherty architecture and advanced process technologies like gallium nitride (GaN).



1. These plots depict a power amplifier's dynamic transfer function with memory effects.

However, higher efficiency comes at a cost—linearity. Poor linearity in cellular systems has two principal consequences: in-band distortions and out-of-band emissions. In-band distortions disrupt the fidelity of the transmitted signal and can be represented by a degradation in error-vector-modulation (EVM) performance. Out-of-band emissions break the 3GPP emissions mask and may cause unwanted interference to operators occupying adjacent channel frequency allocations. We typically measure this aspect of performance in terms of adjacent-channel leakage ratio (ACLR).

GaN PAs offer an additional challenge in that in-band distortions also are produced by the charge-trapping effect.

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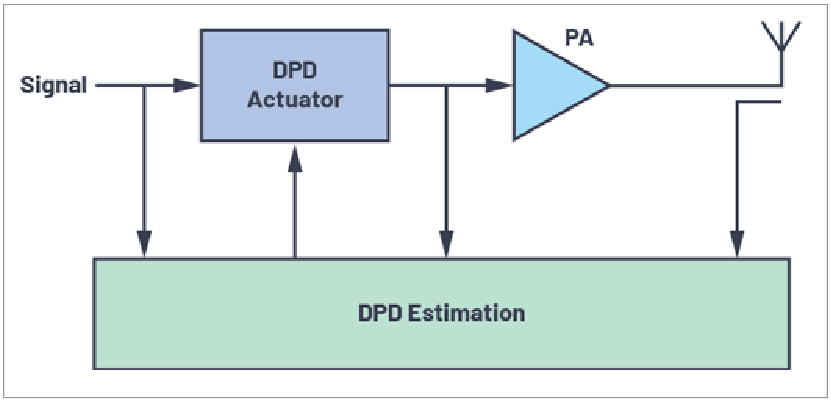
They're dynamic in nature and unrelated to any signal-to-noise ratio (SNR) implied from the ACLR.

Correcting the PA's nonlinearity is essential. It's a reasonable assumption that if one knew the transfer function of the PA, employing its inverse on the data would nullify the nonlinearities. However, the PA has what may be considered a dynamic transfer function; its output-to-input characteristics can be thought of as continuously in flux.

Furthermore, the dynamic transfer function *(Fig. 1)* depends on a combination of the PA characteristics (including power, voltage, and temperature), the input signal presented to the PA, and prior signals that the PA has processed (memory effects). The dynamic nonlinear behavior of the PA must be modeled before it can be corrected, hence the requirement for digital predistortion (DPD). Moreover, the DPD needs to be adaptive to the dynamics of the environment.

Figure 2 depicts the core elements for many DPD systems: observation, estimation, and actuation. The concept in *Figure 2* generates a model that tracks the expected response of the PA so that an appropriate cancellation signal can be generated to nullify the predicted nonlinear behavior of the PA. There are many models, such as the ubiquitous generalized memory polynomial (GMP).

A PA operating in its linear region generates less out-of-band distortions and as shown in *Figure 3*, has a notable reduction in the level of noise that leaks into the adjacent channels. The screenshot is from a spectrum analyzer on a typical DPD test bench, which is used to demonstrate static DPD performance that meets the standards required by many ACLR compliance tests.



2. Shown is a conceptual representation of a digital predistortion system.

3. These plots illustrate adjacent channel leakage before and after application of digital predistortion.

Market Evolution, Performance Enhancement, and a Moving Target

DPD has been utilized commercially in some 8 million cellular base stations since the 1990s. As the technology and generational requirements of the cellular market have changed (2G, 3G, 4G, and now 5G), so too have the requirements placed on DPD. Those challenges include, but are not limited to, wider bandwidths, higher powers, carrier placements, higher peak-to-average signal ratios, and densification in the number and proximity of base stations.

Equipment vendors are anxious to differentiate their product offerings and continue to push for performance enhancement in terms of efficiency relative to the relevant 3GPP specification. PA efficiency continues to present a challenge. Whereas traditional drivers of change would have been OPEX costs and thermal management (including the hardware/weight costs associated with it), environmental considerations are now accelerating that change.

PAs and DPD share a partially symbiotic relationship. In some instances, that relationship can be harmonious and in others more difficult. A PA that is DPD-friendly with DPD from one supplier may struggle with that from another. Often, optimal performance is achieved when both DPD and the PA are configured and tuned to match the specific application. However, because PA design continuously evolves to meet the aggressive requirements of 5G and beyond, DPD must evolve accordingly.

As wideband and dual-band applications become the norm, PA develop-

DPD has been utilized commercially in some 8 million cellular base stations since the 1990s. As the technology and generational requirements of the cellular market have changed (2G, 3G, 4G, and now 5G), so too have the requirements placed on DPD.

ers are challenged on how to achieve wider bandwidths at higher frequencies while maintaining performance expectations. Developing a PA with a bandwidth capability of 200 MHz and beyond is a challenge. Ensuring that it also can meet 3GPP specifications and efficiency creates further challenges. These challenges, in turn, fall back on the DPD developers.

Understanding the Challenge

Quantifying DPD performance isn't a straightforward task. A matrix of conditions and scenarios should be considered—in addition to the PA, there's a slew of other mitigating dependencies. When we consider performance, the specifics of the test conditions must be clearly defined: Achieving >50% efficiency at a bandwidth of 200 MHz is a much greater challenge than the same level of efficiency at an operating bandwidth of 20 MHz.

The situation becomes more complex when we consider carrier placement within the allocated spectrum. It may be a contiguous signal, but it also may be a segmented carrier allocation in which portions of the spectrum are occupied.

At a high level, there are quantitative indicators of DPD performance—the data points primarily defined by the 3GPP specification or operator requirements: ACLR, EVM, and efficiency. Meeting these are just the tip of the DPD performance iceberg. If we add stability and robustness to the mix, the enormity of the challenge starts to surface. Two critical aspects define DPD performance: the static bench-level performance and the real-world operational dynamic performance.

To characterize the challenge of dynamics, *Figure 4* illustrates signal evolution in a dynamic environment and shows how the ACLR might respond to a continuously adapting DPD. The numbers are notional. The plot provides an example of the effect of abrupt signal changes, which are extreme but legitimate. As the signal changes, the DPD model adapts to it. Adaptation events are indicated as dots.

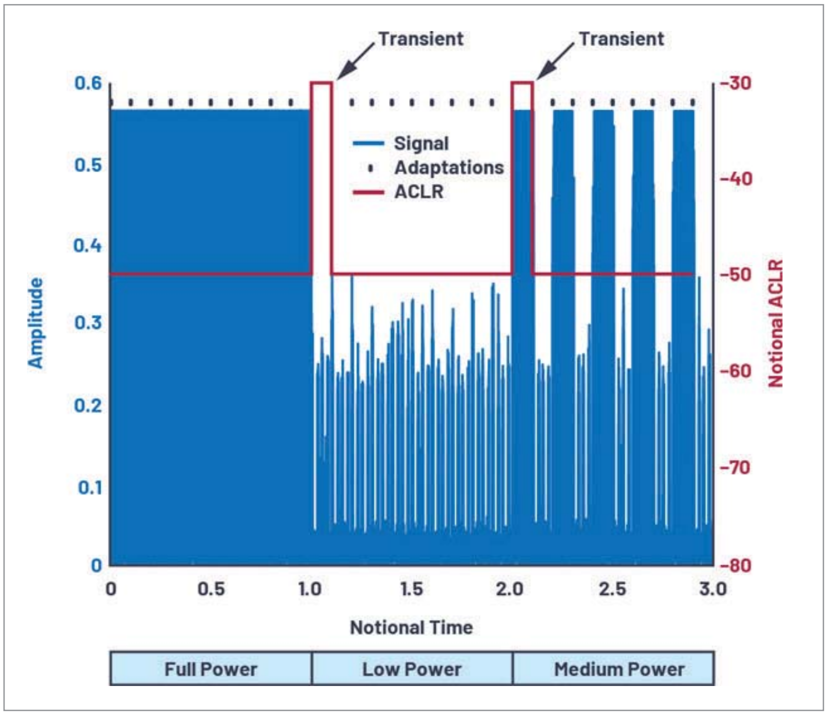
In the transition time between a signal change and the next adaptation, a mismatch occurs between the model and the signal. Therefore, the ACLR value can rise, increasing the risk of exceeding the emissions specification for the duration of the transient.

Adaptation takes a finite time, so there will always be a transient. The challenge for high-performance DPD is to reduce that model mismatch time to a minimum while also ensuring a smooth transition between both states. The process must be managed so that speed of adaptation and disruption to ACLR are both considered.

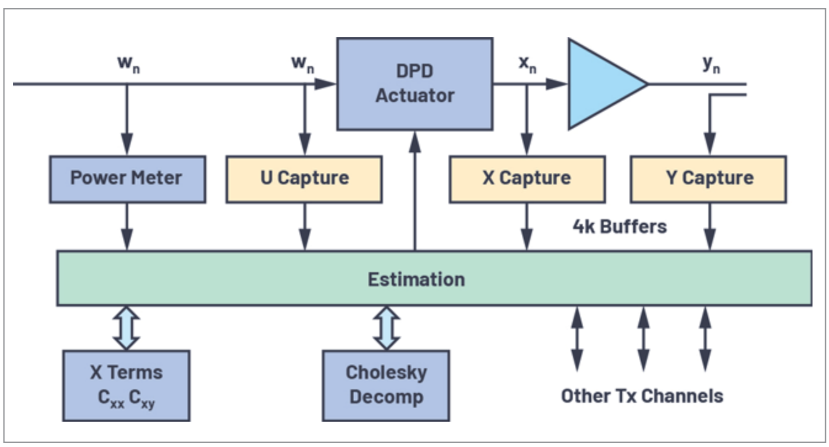
It's important to understand how the model mismatch depends on the nature of the signal transitions. When the mismatch is high, DPD risks degrading performance or, even worse, the stability of the radio. Instability, should it occur, can see the DPD algorithm spiral out of control, blasting emissions masks and, in worst-case scenarios, damaging the radio hardware. On the seesaw of performance vs. stability, stability will always be the prominent design consideration. A DPD design must be robust to ensure stability and error recovery under normal and abnormal operating conditions.

The challenge for a high-performance, practical DPD solution can be summarized in these requirements:

- Static performance (compliance testing or where the BTS traffic load is approximately constant): ACLR and error-vector magnitude (including GaN as a special case)
- Dynamics
- Robustness



4. Shown in this plot is an example of abrupt signal changes and how the ACLR might respond to a continuously adapting DPD.



5. This DPD implementation features more extensive data capturing/observation.

In addition, because Analog Devices is a third-party vendor of DPD, the following also must be considered:

- *Maintenance:* The resolution of performance issues that occur when our customer (the OEM) deploys to its customer (the operator).
- *Evolution:* During its lifetime in the field, the PA technology and signal-space application can change.
- *Generality:* An OEM can fine-tune its DPD to each product. We don't have that luxury. We must meet the needs of many applications while minimizing configurability and redundancy.

Progressing DPD Performance to Meet the Challenges

If we consider static performance alone, there's an element of linear pro-

gression to DPD development. Namely, if we provide more resources, then we enhance performance. For example, more GMP coefficients help to model the PA behaviors more accurately. Thus, as bandwidths widen, this becomes one element of a strategy to maintain, if not improve, performance.

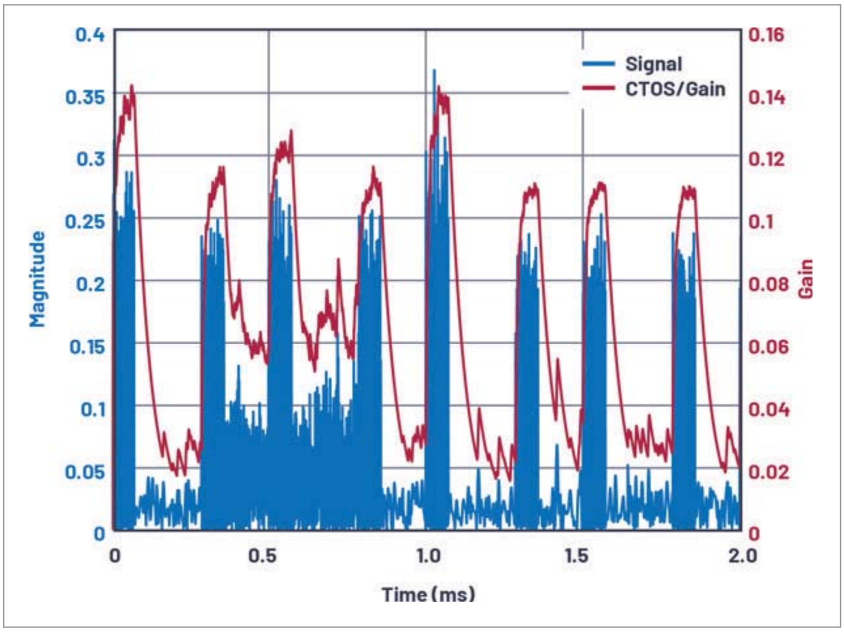
However, such an approach has its limitations. A point of diminishing returns will be reached at which additional resources provide little or no benefit. DPD algorithm developers need to take more creative approaches to eke out further enhancements. ADI's approach is to augment the base algorithm GMP with more general basis functions and higher-order Volterra products.

As developers attempt to create a model that will accurately predict the PA behavior, data accumulation and data manipulation are core essential elements. Capturing data at successive time and power levels gives developers a more complete reservoir or armory from which to make their assessments and shape model behavior.

Figure 5 provides a conceptual overview of a system adopting such an approach. Note the more extensive data-capturing/observation nodes coupled with the digital power monitoring. Power monitoring helps with dynamics. Previously stored models can be brought into play in various ways to mitigate the dynamic transients discussed above.

In recent years, GaN PA technology has brought about an additional challenge for DPD developers: long-term memory effects. GaN process technology brings with it many distinct advantages in terms of efficiency, bandwidth, and operating frequency. It does exhibit what's known as the charge-trapping effect, though.

Charge trapping in GaN is a long-term memory effect, where there's a trap and then a thermal de-trap. GMP-based DPD corrects some of the error. However, residual error continues to impact signal quality. This distortion induces a corresponding rise in EVM. *Figure 6* provides a graphical representation of the phenomenon. Note the PA gain fluctuations and the temporal nature of those fluctuations. Also note the trap and de-trap states and that de-trapping occurs on the lower power symbols.



6. Long-term gain errors were introduced by GaN PA charge trapping.

DPD that has narrow margin to the specification may not be welcomed, while DPD that causes temporary specification extrusions may unsettle operators. DPD that goes unstable and results in illegal emissions and possible PA failure is disastrous.

As the temporal effect is long-term, traditional approaches would suggest the acquisition of a very large number of sample points and, hence, a large amount of data to be stored and processed. Memory costs, silicon area, and processing costs mean that this approach isn't a feasible option for commercial DPD deployments. DPD developers must negate the effects of charge trapping but do so in a way that lends itself to efficient implementation and operation.

Charge-trap correction (CTC) is a feature supported at low cost in terms of power and compute time in ADI's ADRV9029 transceiver. It's been shown to recover the EVM to a level that's within the EVM 3GPP specifications. A next-generation transceiver, the forthcoming ADRV9040, boasts a more elaborate solution that's planned to deliver enhanced performance in dynamic scenarios and better coverage against what are an increasing number of GaN PAs with unique charge-trap personalities.

As stated, the stability of a DPD implementation is of utmost importance. Robustness is addressed by continuously monitoring the internal state and providing rapid responses to unusual conditions.

The generality of ADI's solutions is addressed by testing on a wide sample of PAs from many vendors—a large percentage of whom a symbiotic technical relationship is established.

Conclusion

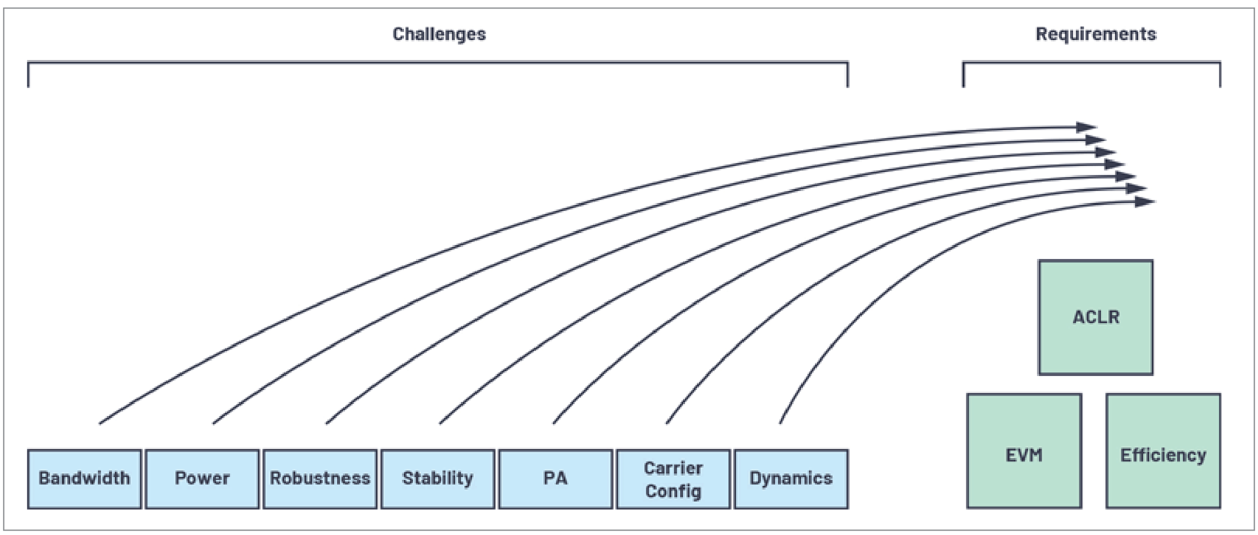
All too often when DPD performance is being presented, the focus is on the static elements of performance. While the yardstick of measurement in terms of EVM and ACLR remain valid, more attention must be paid to the matrix of operating conditions and requirements that frame those measurements. The demands of 5G NR continue to push application requirements. This, coupled with the desire for higher PA efficiencies, compounds the challenge of DPD algorithm development.

As we start to qualify DPD performance *(Fig. 7)*, we need a holistic approach that handles:

- Static performance
- Dynamic performance
- Robustness
- Stability

DPD that has narrow margin to the specification may not be welcomed, while DPD that causes temporary specification extrusions may unsettle operators. DPD that goes unstable and results in illegal emissions and possible PA failure is disastrous.

A DPD algorithm should not be considered an off-the-shelf item. Optimal performance is achieved when the DPD is pruned to the specifics of the PA and the application. Hence, algorithm agility and development/field support also are important considerations. An effective DPD algorithm can deliver substantial system benefits. The complexity of the requirements and the performance assessment should not be underestimated. mw



7. A holistic approach to DPD assessment balances all of the elements of DPD performance with the challenges.

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Thermal Analysis is Vital for High-Power MMIC, MCM, and RF PCB Apps

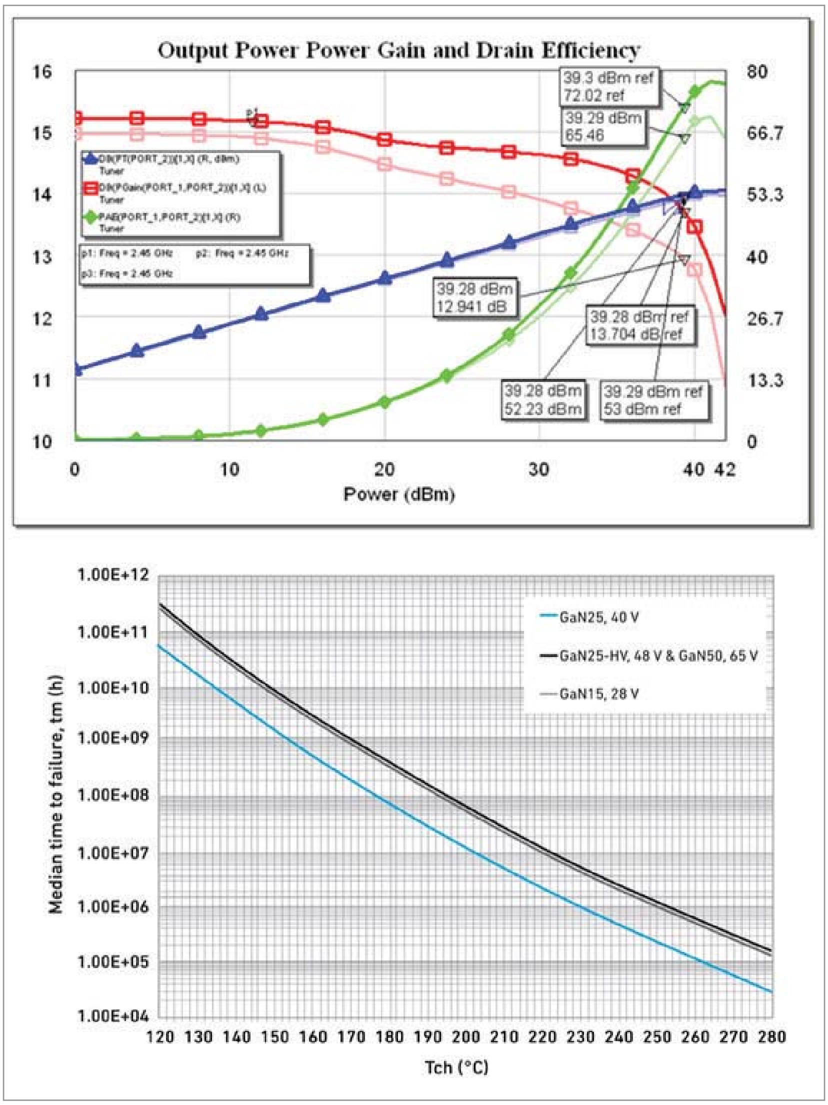
Concerns about power-amplifier heating and operating temps aren't new as they affect device reliability and performance. However, RF designers must broaden the scope of thermal management to include the package, PCB, and surrounding electronics.

RF/microwave power amplifiers (PAs) dissipate power, which leads to a rise in operating temperatures that can extend from the single IC stage to an entire, highly integrated RF system. Higher temperatures degrade both the immediate and long-term performance of RF electronics.

Such temperatures are directly linked to reduced device lifetime or mean-time-to-failure (MTTF) for metal semiconductor field-effect transistor (MESFET), pseudomorphic high-electron mobility transistor (pHEMT), and heterojunction bipolar transistor (HBT) devices used in gallium-arsenide/gallium-nitride (GaAs/GaN) monolithic microwave ICs (MMICs). Reliability and MTTF are of special concern for harsh environments and hard-to-service applications, such as remote base stations and satellite communications.

RF designers need to expand their concern for thermal management beyond PAs to include the package, PCB, and surrounding electronics. It's important to determine the channel temperature for devices based on the large-signal operating conditions, dissipated power, device geometry, and heat-sinking properties of the device and its environment.

For that reason, PA development teams increasingly rely on a mechanical-engineering or thermal-analysis team to investigate operating temperatures either through thermal simulations or measurements. However, this can lead to delays in the overall design cycle.



1. Here we show GaN HEMT performance with and without self-heating on the right (image courtesy of Cree) and GaN device MTTF-vs.-thermal conduction heating (TCH) on the left. *(image courtesy of Qorvo)*

By introducing thermal simulation within the RF/microwave circuit design flow, engineering teams can significantly reduce turnaround time by obtaining temperature information that impacts performance during the design phase. This article describes a simulation workflow that supports thermal analysis directly within an RF design framework.

Today's Thermal Challenges

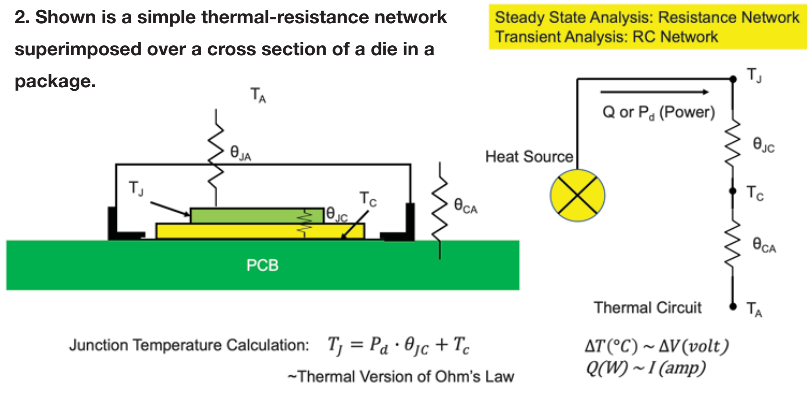
Virtually every modern hardware application uses wireless communications and sensing to connect devices. Such wireless connectivity thus requires that RF technology be an integral part of the system that must coexist with high-speed digital and analog signals across chip, package, and board physical designs.

With the system trend to shrink footprints while integrating more electronics, the importance of electromagnetic (EM) and thermal analysis at the point of design has become critical to efficient and successful system development.

RF engineers, and in particular PA designers, are concerned about device heating and operating temperatures because of the effect on device reliability and performance. The dc power that PAs don't convert into RF energy is converted into heat, and the electrothermal effects impact RF performance with the dominant drain-lag effect dependent on both the voltage bias and the channel temperature. Device channel temperature is a primary source for thermal degradation mechanisms, leading to shortened device lifetimes *(Fig. 1)*.

GaN transistors provide higher output-power densities, wider bandwidths, and improved dc-to-RF efficiencies than their GaAs counterparts. However, to take advantage of this enhanced performance, designers need to accurately capture the complex behaviors of the device during circuit simulation, including thermal effects generated by the GaN device itself. Among the trapping effects related to channel temperature in aluminum GaN HEMTs are transconductance frequency dispersion, current collapse, gate- and drain-lag transients, and restricted microwave power output.

2. Shown is a simple thermal-resistance network superimposed over a cross section of a die in a package.



Furthermore, as with all semiconductor devices, the reliability of silicon-on-carbide (SiC) MESFET and GaN HEMT devices depends directly on maximum operating channel temperature. It's therefore important to determine with a high degree of confidence what the maximum channel temperature is under specific operating modes—particularly for products operating under continuous-wave (CW) conditions and dissipating large amounts of thermal energy. When designing PAs, it's crucial that the transistors operate below their rated operating junction or channel temperatures to ensure that the amplifier will have the desired reliability.

How much heat can be generated by a typical high-power GaN PA that might be found in a base station? A GaN HEMT, for example, with a gate periphery of 28.8 mm operating at a drain voltage of 28 V delivers 120 W of CW power. At a 60% dc-to-RF conversion efficiency, there will be 80 W of dissipated heat, which translates into a heat density of over 20 kW per square inch.

This heat will be dissipated from the device channel to the package and PCB though structures such as wire bonds, grounding vias, and the semiconductor and package materials themselves. Designers need to ensure that the device is operating below the rated operating junction temperature. Thus, they're interested in knowing that value and lowering it, if possible, through structures such as wire bonds, grounding vias, and heatsinking strategies, all of which can be optimized through analysis.

Thermal Analysis for RF Applications

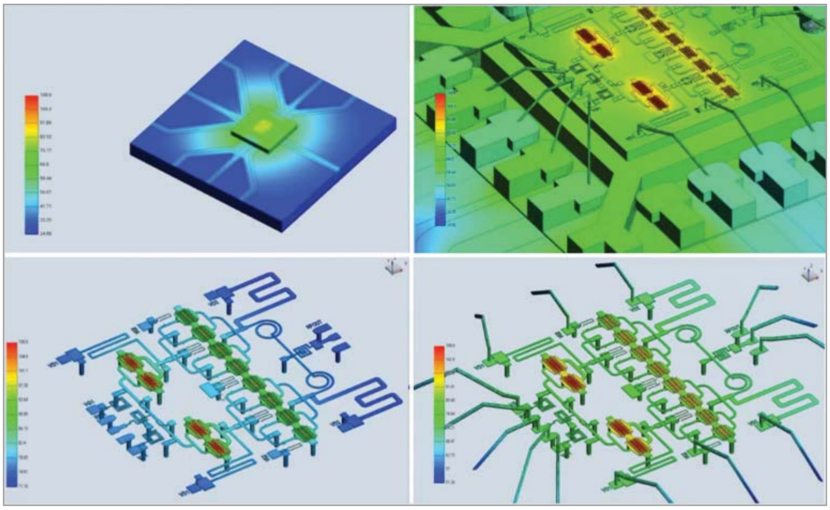
Heat maps illustrate device-generated hot spots and the thermal challenges posed by densely packed electronics. Within the IC, performance can be compromised by rises in temperature. In packages/PCBs, thermal problems arise due to Joule heating, which affects IR drop and performance. In the broader system context, we need to identify hot spots and implement a cooling strategy.

To study the temperature resulting from power dissipation, thermal-analysis tools can be combined with nonlinear RF circuit simulation tools to provide the needed power-dissipation information. When combined, the RF circuit simulator and thermal-analysis software provide critical operating temperature information for both in-design and signoff.

A simple thermal resistance network, shown superimposed over a cross section of a die in a package in *Figure 2*, helps illustrate heat flow in a quad flat no-lead (QFN) package. The PA MMIC is embedded in the QFN package, which is sitting on top of the PCB.

The thermal circuit has a heat source with the power (Q) flowing from the junction to the bottom case of the package, then to the outside world (ambient temperature). Some of the heat will flow from the junction to the case of the package and spread into the board, and then out through the air or some other conduction path.

The thermal version of Ohm's law shown at the bottom of the diagram is used to calculate the channel temperature of the PA MMIC, which is equal to the power dissipation times the thermal resistance plus the case temperature that could come from the thermal model results. We can obtain a much more rigorous and accurate prediction of temperature through 3D planar modeling of the devices, with material conduction properties and simulated power dissipation coming from nonlinear harmonic-balance (HB) circuit simulation.



3. These images represent various heat-map views of the full 3D structure: Power across the board (upper left), heat sources spread across the MMIC's power transistors (upper right), the die metallization (lower left), and with the wire bonds added (lower right).

Integrated Thermal-Analysis Workflow

RF designers using software that offers multiple integrated tools can obtain operating temperature and heat maps of their RF device, package, and PCB system with direct access to the thermal solver through the circuit simulator. The tools perform their schematic simulations, produce power dissipations, and then automatically generate a thermal model and simulations.

Cadence's Celsius Thermal Solver, for example, offers finite-element analysis (FEA) to accurately determine the operating temperature using an adaptive meshing algorithm. The algorithm works with the Celsius Thermal Solver's workbench to illustrate thermal heat mapping and automatically report the operating temperature for all defined heat sources in the AWR Design Environment platform.

Thermal analysis can be applied immediately during simulation to improve simulation accuracy, including thermal effects, enabling problems to be discovered early on. In addition, the mechanical computer-aided design (MCAD) and power-dissipation data can be handed off in parallel to a mechanical/thermal engineer for final signoff, if needed.

MMIC PA Example

This example demonstrates how integrating the Cadence Celsius Thermal Solver within Microwave Office circuit design software enables thermal analysis of a high-power X-band MMIC PA in a QFN package on a PCB. The design is initially simulated in the APLAC HB solver, after which the power information from all of the devices within the design is sent to the Celsius Thermal Solver. There, the chip is simulated inside the QFN package on a PCB to see how the power is distributed across the different technologies.

Once the simulation is completed, we can view the full 3D structure *(Fig. 3)*. The power across the board can be seen at upper left and the heat sources spread across the different power transistors of the MMIC at upper right. By turning off the visibility of any of the layers, one may view single layers. The visibility of the package and board structures can be turned off to examine the temperature across the die metallization represented with the heat map (bottom left), as well as with the bond wires made visible (lower right).

The scale for temperature distribution dynamically changes as structures are made visible or removed. The cut setting can be selected to slice the structure for a cross-section view of the localized hotspots in the x, y, and z directions.

A results summary shows temperatures of the heat sources of the individual field-effect transistor (FET) fingers, which are reported back into the circuit simulator. For this example, the average temperature across each gate finger is 92.6°C for a simulated power dissipation of 2.9 W. This flow enables the designer to simulate closer to the edge of the design space, allowing the PA's performance to be maximized because a large thermal margin doesn't need to be left on the table from a safety standpoint. The design also can be studied to see the effects of other options, such as putting the die on a heatsink, on temperature distribution to optimize performance.

Conclusion

This article discussed the importance of thermal analysis for RF power applications. As PCBs become more densely populated with devices, the operating temperatures of those devices impact the reliability (device lifetime) and performance.

A thermal-analysis flow using a thermal solver integrated within the circuit simulator gives designers an understanding of device operating temperatures related to power dissipation. Subsequently, that temperature information can be inserted into an electrothermal model to predict the impact on RF performance. This flow provides RF engineers with ready access to operating temperature data for reliability and performance studies early in the design process. mw

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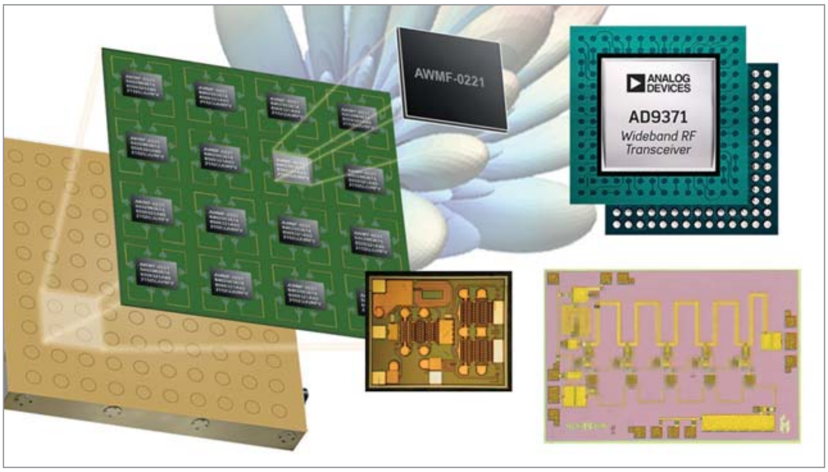
JACK BROWNE | Technical Editor

RFICs and MMICs Aim at SWaP Targets

Designers of aerospace and defense electronic systems look to more efficient RFICs and MMICs with increased functionality to achieve solutions with ever-smaller SWaP.



Solid-state devices and circuits have long been mainstays of aerospace and defense electronic systems, even in the face of rising signal frequencies and power levels. As military system designers become more concerned with smaller size, weight, and power (SWaP), they have looked to RF integrated circuits (RFICs) and monolithic microwave integrated circuits (MMICs) to provide more high-frequency functionality with higher efficiency. Among their applications are communications, electronic-warfare (EW), and radar systems, including those moving into space aboard satellites.

The trend in RFICs and MMICs for aerospace and defense use has been greater integration at higher frequencies, whether as bare die or in packages. Although major defense contractors, such as BAE Systems, Northrop Grumman, and Raytheon Technologies have their own gallium-nitride (GaN) and gallium-arsenide (GaAs) foundries, they rely on a variety of sources for different RFICs and MMICs to accomplish more with less in modern electronic systems.

Active RFICs and MMICs perform essential functions in defense systems for antennas, data conversion, frequency conversion/mixing, switching, signal generation, and amplification. Passive MMICs provide functions such as attenuation, coupling, and filtering. Multiple-function MMICs replace what had once required separate components. However, increased circuit density packs energy tighter and heat must be dissipated efficiently as part of any SWaP planning.

Whether as chips or in packages, ICs for aerospace and defense must be capable of difficult operating environments, such as operating temperatures from −55 to +85°C. ICs for space must meet even more challenging benchmarks, such as operating temperatures from −55 to +125°C, Class K and Class S parameters, and space-qualified MIL-PRF-38535 requirements. As needed for high-reliability (hi-rel) applications, RFICs and MMICs can be screened, for example, to even higher operating temperatures.

Meet the Makers

High-frequency industry developers and suppliers of RFICs and MMICs for military/aerospace and other applications are expected to be on hand at the 2022 Radio Frequency Integrated Circuits (RFIC) Symposium at the Colorado Convention Center (Denver). It's scheduled for June 19-21, 2022, as part of "Microwave Week" during the 2022 IEEE International Microwave Symposium (IMS) when the Automatic RF Techniques Group (ARFTG) meeting brings together those interested in RF test and measurement methods.

One of the more diversified RFIC/MMIC portfolios for aerospace and defense belongs to Analog Devices. The company's ICs are based on GaAs, GaN, silicon (Si), and silicon-germanium (SiGe) substrates for functions such as clock generation and timing, data conversion, frequency generation, and signal amplification. Analog Devices promotes its IC products as an "antenna to bits" portfolio, with the assurance of full product testing by measure of digital test capabilities to 40 Gb/s and RF/microwave test capabilities to 110 GHz.

One of the company's "simpler" RFICs is the ADAR3000, an antenna beamformer for transmit and receive operation from 17 to 22 GHz *(Fig. 1)*. Time delays and step attenuation can be programmed to form 4 beams and 16 channels, with SPI computer control. While the antenna beamformer fits within a chip-scale BGA package, even more impressive is that the same BGA package contains an integrated analog-to-digital converter (ADC) and memory for storing beam positions. The beamformer IC has an operating temperature range of −40 to +85°C.

1. The ADAR3000 is a silicon MMIC beamformer that controls the beams of radiating elements from 17 to 22 GHz. *(Courtesy of Analog Devices)*

The same company's model AD9371 wideband transceiver IC is a bit more complex, integrating multiple transmitters and receivers for applications from 0.3 to 6.0 GHz. It's well-suited for commercial, industrial, and military applications including EW systems, portable radios, satcom systems, and data links in unmanned aerial vehicles (UAVs).

The MMIC, housed in a 196-ball chip-scale ball-grid-array (CS-BGA) package measuring just 12 × 12 mm, contains components for pairs of differential transmitters and receivers and several other receivers that at one time would have filled several 19-in.-wide equipment racks *(Fig. 2)*. The various receivers handle bandwidths from 7.5 to 100.0 MHz, and the differential configuration allows for the use of frequency-division-duplex (FDD) and time-division-duplex (TDD) antenna systems.

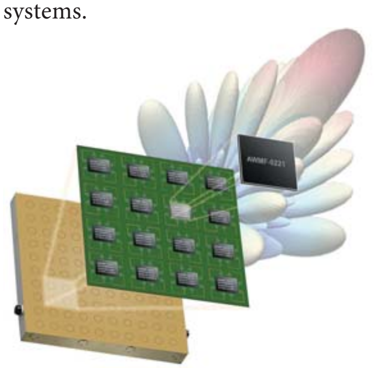
2. A chip-scale package measuring 12 × 12 mm holds silicon ICs containing several sets of transmitters and receivers operating to 6 GHz. *(Courtesy of Analog Devices)*

Silicon ICs for Antennas

Anokiwave is well-versed in the design and production of active-antenna silicon ICs, especially beamforming ICs for phased-array antennas working through mmWave frequencies. The company's ICs, which serve military and aerospace applications as well as commercial markets like satcom and 5G networks, are developed with goals of high performance, low cost, and small size in mind. The beamforming ICs provide precise control of signals to additional radiating elements as part of a phased-array antenna capable of directing and steering EM beams for receiving and transmitting purposes.

As an example, model AWS-0104 is an X-band beamforming IC that operates from 8.50 to 10.55 GHz. It connects to four radiating elements to form single beams for transmission and reception, with the operating mode controlled by an additional transmit/receive switch. Running from a single power supply, the IC provides 6-bit gain and phase control of the beams to steer and shape the beams during transmit and receive modes. The compact, low-power antenna solution targets communications radios and active electronically scanned array (AESA) radar systems.

At higher frequencies and with a bit more complexity, the firm also offers the AWMF-0221 dual-polarized Si CMOS beamforming IC for use from 24.25 to 29.50 GHz *(Fig. 3)*. Designed to cover specific 3rd Generation Partnership Program (3GPP) bands, including n258, n257, and n261, in 5G networks, the IC can be operated with four dual-polarized or eight single-polarized channels, controlling radiating elements in a phased-array antenna. Its beamsteering controls are compliant with all 3GPP standards, and the IC is designed with strict carbon-neutrality goals in mind to support environmentally safe "green" electronic systems.



3. This silicon CMOS MMIC orchestrates antenna beamforming from 24.25 to 29.50 in phased-array antennas. *(Courtesy of Anokiwave)*

Renesas Electronics Corp. has developed several generations of silicon ICs for antenna beamforming applications, with separate ICs for radar and Ka- and Ku-band satcom receive and transmit beamforming functions as well as LNA MMICs to aid the receive functionality. The ICs are available as 16-channel, dual-beam receive beamformers (which can be programmed for single-beam use), and 8-channel transmit beamforming ICs.

The three receive beamformer ICs cover frequency bands of 10.70 to 12.75 GHz, 14.0 to 17.0 GHz, and 17.7 to 21.2 GHz, while the transmit ICs cover bands of 13.75 to 14.50 GHz, 14.0 to 17.0 GHz, and 27.5 to 31.0 GHz. Additional suppliers of RFICs for beamforming applications, although only for commercial bands and applications, include pSemi and Qualcomm.

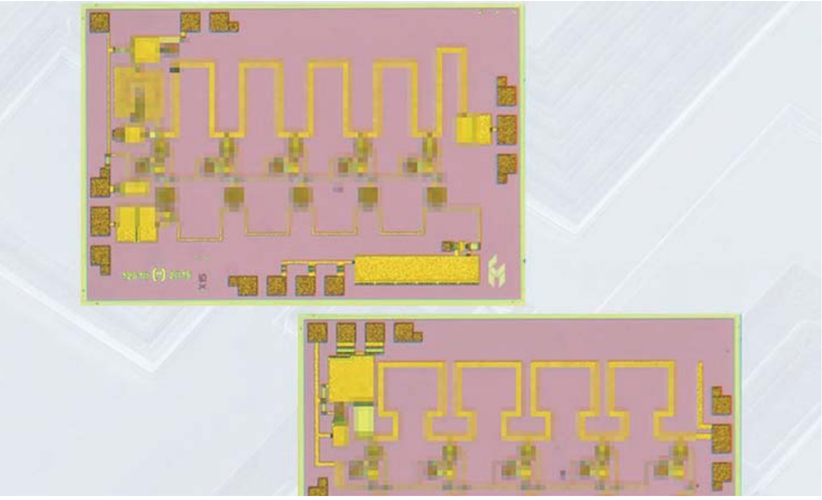
Microsemi Corp., once a part of Microchip and now in the fold of Mercury Systems, offers a broad range of RFICs and MMICs including switches, prescalers, and frequency/phase detectors for EW, radar, and test applications from dc through 65 GHz. Its PFD1K phase frequency detector can be used with input frequency references and voltage-controlled oscillators from 10 MHz to 40 GHz to create phase-locked-loop (PLL) frequency sources.

The device packs a pair of 7-bit prescaler dividers and an 8-GHz phase frequency detector into a 6- × 6-mm ceramic QFN package. It runs on a single positive or negative 3.3-V dc supply and inputs and outputs can be used in single-ended or differential modes. The model MMS006AA GaAs MMIC single-pole, double-throw (SPDT) switch operates from dc to 20 GHz with less than 2-dB insertion loss and more than 40-dB isolation between ports. Typical switching speed is 10 ns.

Qorvo, created from the merger of former RF semiconductor innovators TriQuint Semiconductor and RF Micro Devices and the combination of Custom MMIC, also offers miniature packaged front-end modules for commercial communications and commercial and military radar systems. However, they're achieved by integrating multiple amplifier, limiter, and transmit/receive switch dice within a multipin, surface-mount package.

The model QPF5005 front-end module spans 8 to 12 GHz with a receive noise figure of 2.2 dB and transmit power of +47 dBm (5 W). For those in need of more transmit power, model QPF5010 covers the same frequency range with the same receive noise figure, but it delivers typically +40 dBm (10 W) transmit power.

One product that made the transition from Custom MMIC, the model CMD310C3, is a subharmonically pumped MMIC mixer with an integrated local oscillator (LO) housed within a leadless QFN package. It covers an RF range of 20 to 32 GHz with the LO operating at 10 to 16 GHz and yielding an intermediate-frequency (IF) range of dc to 6 GHz. The conversion loss and single-sideband (SSB) noise figure are both 8.5 dB, while the RF input power for 1-dB compression is +3 dBm. The mixer/LO MMIC draws 27 mA from a +4-V dc supply.



4. This GaAs MMIC distributed amplifier is supplied in die form for applications from dc to 22 GHz. *(Courtesy of Qorvo)*

The company also offers GaAs MMICs in die form, such as the model CMD240 *(Fig. 4)*, a distributed amplifier with more than 15 dB gain and low 2.2-dB noise figure from dc to 22 GHz. The chip amplifier is fully passivated for protection from damage caused by water vapor absorption in high humidity.

A relative newcomer, Viper RF, offers standard and custom discrete transistors and MMICs to 150 GHz, including the VRFC0127-BD C-band single-chip front-end MMIC. It operates from 5.2 to 5.6 GHz and integrates a transmit/receive switch, power amplifier, and LNA. Well-suited for radar and satcom, the receiver function achieves noise figure of 2.4 dB and small-signal gain of more than 35 dB at 5.4 GHz. The transmit saturated output power is typically +47 dBm at 5.4 GHz with power-added efficiency (PAE) of better than 40%. The front-end chip measures 5.89 × 6.70 mm.

Keep it Simple

Complex multifunction ICs can often replace larger, higher-power modules based on discrete components. RFICs and MMICs designated for military duty contribute to military electronic system SWaP goals by replacing single-function discrete components such as amplifiers, mixers, and switches, albeit with less power-handling capabilities.

For example, the MMA-012030 from MicroWave Technology Inc. is a broadband GaAs MMIC traveling-wave amplifier in die form. Measuring just 2350 × 1050 µm, it's capable of 0.5 W (+27 dBm) output power at 1-dB compression from 0.1 to 20.0 GHz. The amplifier consumes 6 W power (0.5 A at +12 V dc) but maintains 12.5-dB gain flat within ±0.5 dB across the full wide bandwidth. It's one example of an extensive line of broadband MMIC power amplifiers, driver amplifiers, and low-noise amplifiers (LNAs) in chip form for aerospace and defense applications.

Due to the difficulty of maintaining low amplifier noise figure over broad bandwidths, the firm offers die amplifiers such as the MLA-01122B GaAs MMIC LNA with optional 50-Ω on-chip impedance matching by means of microstrip interconnection to additional tuning stubs. The MMIC LNA, measuring 1.57 × 1.31

× 0.1 mm, is a good fit for EW and satcom receivers, drawing just 55 mA from a +5-V dc supply. It features 1.6-dB typical mid-band noise figure from 1 to 12 GHz with 17-dB gain that's flat within ±1.5 dB. Typical output power at 1-dB compression is +16.5 dBm.

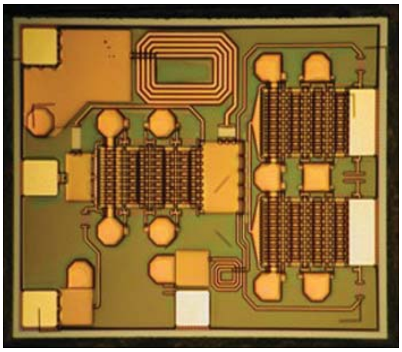
Among the most broadband of MMIC amplifiers, the model MMA0035AA eight-stage traveling-wave die amplifier from Microsemi Corp. has a bandwidth of 0.04 to 65.00 GHz. It employs the company's passive low-frequency extension (PLFX) on-chip circuitry to provide 10-dB small-signal gain flat within ±1.25 dB. It measures just 1640 × 920 μm but has an integrated power detector and dynamic gain control of better than 30 dB.

The amplifier draws 150 mA from a +7-V dc supply. It provides +15 dBm output power at 1-dB compression and +18-dBm saturated output power for extremely broadband applications in communications and EW systems requiring small-signal amplification.

United Monolithic Semiconductors offers LNAs in packaged form and PAs in die form based on GaN and GaAs materials. In die form, the model CHA8212-99F PA supports compact X-band EW and radar systems. It provides +44.5-dBm saturated output power from 8.5 to 11.5 GHz with 34-dB small-signal gain across the frequency range. It achieves 36% PAE at 7-dB compression while drawing 750 mA current from a +28-V dc supply.

For those in need of more bandwidth (but less power), the model CHA7618-99F delivers +40 dBm at 8-dB compression from 0.5 to 18.0 GHz with 30-dB gain. Also in die form, the PA achieves 24% PAE at 8-dB compression. It consumes 800 mA at +18 V dc.

Providing discrete transistors as well as MMIC amplifiers, in flange packages and as bare die, AMCOM Communications works with both GaN and GaAs substrates, too. The AM00010037WN-00 is a GaN MMIC PA with 13-dB small-signal gain from dc to 10 GHz and typical gain flatness of ±1.5 dB. It delivers +37-dBm saturated output power in bare die form with PAE of 23% at 5-dB compression *(Fig. 5)*. Not common for PAs, it's characterized for noise figure, which is quite respectable at 5 dB from 1 to 9 GHz. The MMIC PA draws 400-mA current from a +30-V dc supply.



5. AMCOM's GaN MMIC PA, which provides high gain and low noise figure from dc to 10 GHz, comes in die form. *(Courtesy of AMCOM Communications)*

Another long-time supplier of RFICs and MMICs, MACOM Technology Solutions recently announced that four of its manufacturing sites (in the U.S.) achieved AS9100D certification. The quality management system (QMS) standard, which builds on the ISO9001 military and space standard, designates the highest quality and repeatability of products from these manufacturing facilities, located in Massachusetts, Michigan, New Hampshire, and North Carolina.

MACOM offers a wide range of in-house designed and fabricated RFICs and MMICs as well as integrated assemblies based on those ICs and discrete semiconductors. Among its MMIC amplifiers, the MAAM02350-A2 is a GaAs MMIC PA in an 8-lead ceramic flatpack package. It operates from 0.2 to 3.0 GHz with +14-dBm output power at 1-dB compression and low noise figure of 4 dB. The gain is 18 dB and flat within ±0.75 dB across the full bandwidth.

The MMIC consists of two integrated gain stages with resistive feedback and requires no other external components other than a dc blocking capacitor for the power supply, which is +6 V dc. It typically draws 65 mA from the supply.

pSemi, which recently announced a series of RFICs for 5G frequency-conversion and beamforming applications, has been a long-time supplier of single-function RFICs such as switches and phase shifters for military applications.

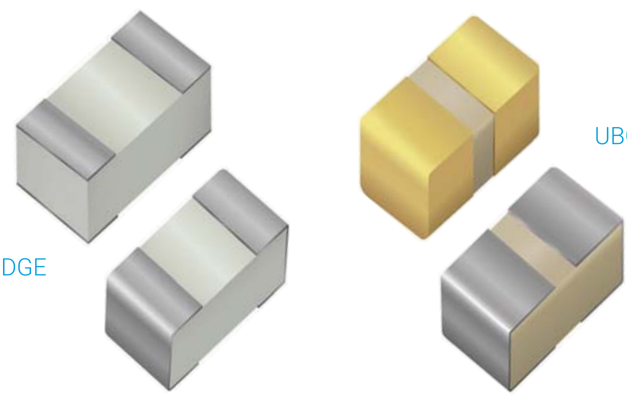
The PE44820 phase shifter, for example, provides precise phase control for weather and military radar systems from 1.7 to 2.2 GHz (with extended operation to 3.0 GHz). It's well-suited for beamforming networks, distributed antenna systems, active antenna systems, and phased-array applications. Fabricated with the company's silicon-on-insulator (SOI) CMOS technology, the RFIC's 8-bit phase shifter provides steps as small as 1.4 degrees. It's designed for temperatures as high as +105°C and holds RMS phase errors under 1 degree and amplitude errors to 0.1 dB or better. The phase shifter comes in a 5- × 5-mm QFN package.

A source not normally associated with GaAs technology—Keysight Technologies—provides one of the most broadband MMIC components, the dc-to-75-GHz model TC950 SPDT switch. Designed nominally for general-purpose and instrumentation applications, the switch also is a good fit for EW, ECM, and pulsed-radar systems. The switch chip, which is fabricated with Microwave Technology's GaAs pHEMT process, measures 630 × 930 μm. It has 2.6-dB insertion loss and 29-dB isolation at 50 GHz.

Mini-Circuits, one of the RF industry's most diversified suppliers of discrete high-frequency components, also offers a wide array of RFICs and MMICs, typically in packaged form. The choice of component functions, such as amplifiers and switches, give system designers the flexibility to weigh overall system performance in quest of SWaP goals.

For example, model PMA-183PLN+ is a 6- to 18-GHz GaAs MMIC LNA in a 16-lead MCLP housing. It provides small-signal gain of typically 26.3 dB at 6 GHz, 27.5 dB at 15 GHz, and 29.7 dB at 18 GHz

KYOCERA AVX



ACCELERATING INNOVATION

KYOCERA AVX has an ever-evolving portfolio consisting of antenna technologies, RF chipsets, broadband components, high-reliability capacitors, and more. Likewise, KYOCERA AVX capacitors are suitable for operation across various applications and industries, including commercial, industrial, telecom, automotive, military, space, and medical.

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with noise figure of typically 1.4 dB at 6 GHz, 1.2 dB at 15 GHz, and 1.3 dB at 18 GHz. It draws 57.2 mA from a single 2.6-V dc supply.

When higher frequency coverage is required, the firm also supplies the model TSS-44+ MMIC amplifier with 17.6-dB typical gain that maintains ±0.9 gain flatness from 22.0 to 40.0 GHz. Typical noise figure is 3.7 dB to 40 GHz. The amplifier is supplied in a 3- × 3-mm MCLP surface-mount package with integrated dc blocks and bias tee.

Among the company's other MMIC components are phase shifters and high-speed switches, such as the model M3SWA2-63DRC+ SPDT absorptive MMIC switch for applications from dc to 6 GHz. It operates on ±5-V dc supplies with 5.6-ns typical rise time and 6.0-ns typical fall time while suffering 1.3 dB or less insertion loss across the full frequency range. The isolation between output ports is 55 dB to 2 GHz and 37 dB to 4.5 GHz.

For the future, the DoD and DARPA are seeking higher-frequency internet access for defense communications systems, notably for many sensors expected to take advantage of Internet of Things (IoT) links via 5G networks.

The MMIC switch comes in a 12-lead package measuring 3 × 3 mm.

Conclusion

For the future, the DoD and DARPA are seeking higher-frequency internet access for defense communications systems, notably for many sensors expected to take advantage of Internet of Things (IoT) links via 5G networks. Some of the highest-frequency antenna ICs provide operation through 110 GHz for satellite links as well as data links with UAVs and unmanned ground vehicles (UGVs).

Still, more bandwidth is always needed and higher frequencies in the spectrum is the place where it's at. This includes the G-band (110 to 300 GHz), where programs such as DARPA's Electronics for G-Band Arrays (ELGAR) project are seeking future MMIC developments. mw

Ad Index

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USB Switch Commands 0.1 to 30.0 GHz

Mini-Circuits' model USB-1SP2T-34 single-pole, double-throw (SPDT) switch has high isolation and low loss from 0.1 to 30.0 GHz. Typical isolation is 55 dB or better, with insertion loss of 2.8 dB to 20 GHz and 4.4 dB to 30 GHz. Switching speed is 2 ms from USB command to change in switch state. Ideal for communications, radar, and test, the 50-Ω switch handles +27 dBm power at 1-dB compression via 2.92-mm connectors and consumes 80 mA from a 5-V dc supply.

MINI CIRCUITS, https://www.minicircuits.com/WebStore/dashboard.html?model=USB-1SP2T-34

Cartridge Fuses Withstand High Currents and Voltages

Littelfuse now offers a compact cartridge-fuse series that's rated at 500 V ac/V dc with current ratings from 40 to 63 A and a 10-kA interrupting rating; the latter suits them for dual voltage-source power supplies. The 607 Series cartridge fuse, designed for overcurrent protection applications, provides a robust solution for demanding high-voltage power-supply circuits. The 500-V fuse rating is suitable for both ac and dc inputs. With a 10- x 32-mm cartridge body, a single 607 fuse requires less board space than previous designs that used multiple lowet-current-rated fuses in parallel. As a result, designers can reduce the board space they reserve for protection components when designing high-wattage equipment. End caps with integrated stand-off leads eliminate the need for mounting accessories or lead-forming processes. Operating temperatures range from -55 to 125°C.

LITTELFUSE, https://www.littelfuse.com/products/fuses/cartridge-fuses/10x32mm-fuses/607

Comb Generators Serve Calibration and EMI Measurement Tasks

EMI Devices now offers three models of comb generators: model WJ10-25A, WJ10-50A, and WJ10- 100A, along with three broadband antennas: model L1600, M2500, and S4500. These product families complement each other and can be used conjointly to conduct daily routine site calibration tasks and many other EMI-related measurements. All three comb generator models are physically small (outside diameter = 73.0 mm, height = 56.0 mm) and are housed in robust high-grade aluminum alloy. They're powered by a rechargeable internal battery. These devices offer long battery operating time, exceeding 40 hours of operational time with a fully charged battery.

EMI DEVICES, https://www.emidevices.com/antennas/comb-generators/

Sealed Wire-to-Wire Connectors Scoff at Harsh Environments

With the launch of its Squba series of sealed wire-to-wire connectors, Molex offers an IP68-rated connector that's certified as resistant to nearly five feet of water for 30 minutes. The connectors' patented design meets the stringent international standard of waterproofing and resistance to dust, dirt, sand, and other contaminants. The 1.80-mm-pitch connector holds a 6.0-A current rating, enabling transmission of more power over smaller-gauge wire for additional space savings and reduced costs. The connector's narrow pitch further alleviates space constraints while availability in 2-to-10 circuits and support for high operating temperatures offer additional product design options. Not only that, but the Squba connectors are made with rubber-molded plastic and include a durable cap to protect the seal from damage during shipping, handling, assembly, and use. As a result, these smaller, ruggedized connectors are optimized for a wide range of applications and wet, dusty environments where connector size, resiliency and quality are paramount. These include consumer devices, commercial vehicles, industrial automation, connected homes, and more.

MOLEX, https://www.molex.com/molex/products/family/180mmpitch_sealed_wiretowire_connectors

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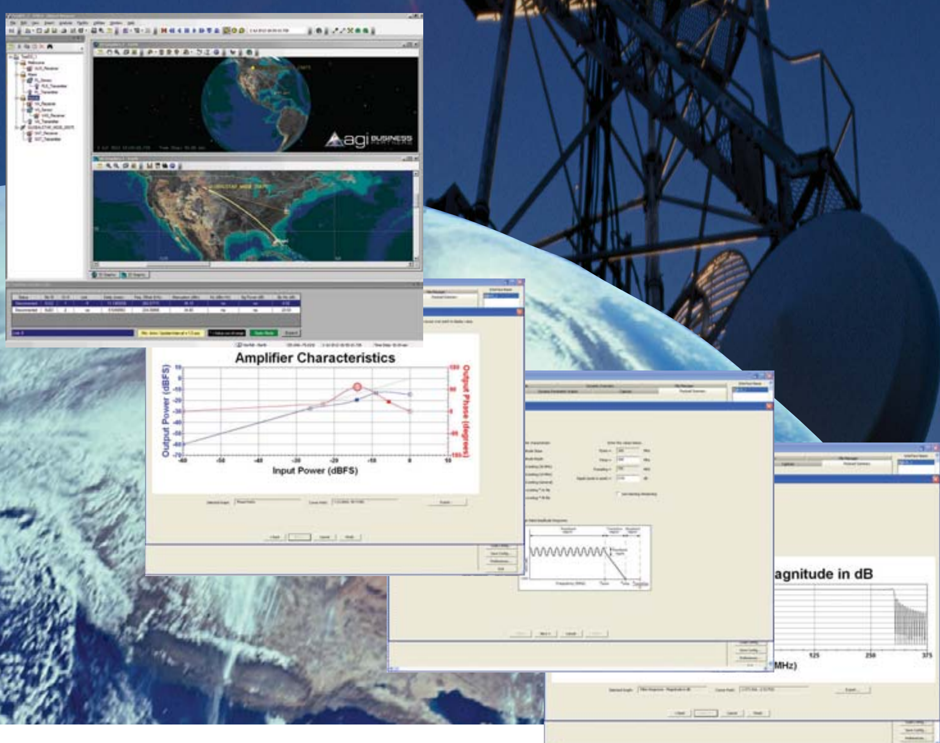

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