

Micro[®]wave Journal

See Yourself At IMS2023



**REGISTER
NOW!**



IMS



11-16
June 2023
San Diego
California

ims-ieee.org



horizon
house[®]

Founded in 1958

mwjournal.com

Vol. 66 • No. 4

April 2023

Micro[®]wave Journal



Founded in 1958

mwjournal.com

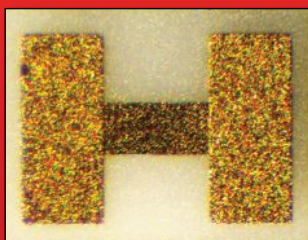


Medical
Telecommunications
Semiconductor
Military
Broadcast
Industrial Laser

High-Q Low ESR
RF Microwave
CAPACITORS



Broadband
RESISTORS



High Power
**CUSTOM
ASSEMBLIES**



Broadband
CAPACITORS



01005 0201 0402 0603 0805

ISO Certified
Quick Deliveries
Competitive Pricing
Inventory Programs
Engineering Support
C.A.P. Engineering Program
Excellent Customer Service



 **Modelithics**®

Contact us today: 631-425-0938 • sales@passiveplus.com • www.PassivePlus.com



Picoprobe elevates probe cards to a higher level...

(...110 GHz to be exact.)

Since 1981, GGB Industries, Inc., has blazed the on-chip measurement trail with innovative designs, quality craftsmanship, and highly reliable products. Our line of custom microwave probe cards continues our tradition of manufacturing exceptional testing instruments.



Through unique modular design techniques, hundreds of low frequency probe needles and a variety of microwave probes with operating frequencies from DC to 40, 67, or even 110 GHz can be custom configured to your layout.



Our patented probe structures provide the precision and ruggedness you require for both production and characterization testing. And only Picoprobe® offers the lowest loss, best match, low inductance power supplies, and current sources on a single probe card.

Our proven probe card design technology allows full visibility with inking capability and ensures reliable contacts, even when probing non-planar structures.

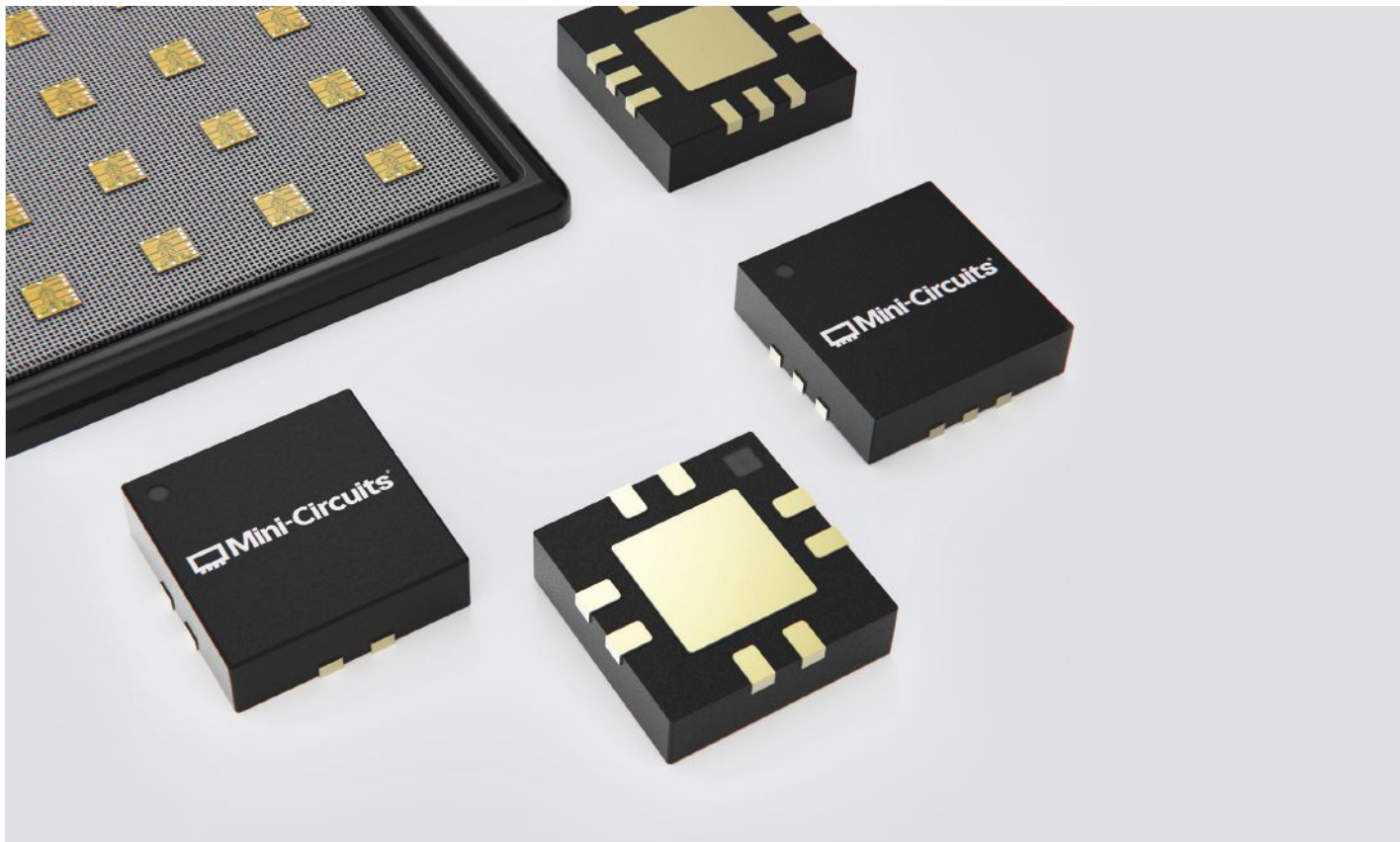
Not only do you get all the attractive features mentioned, but you get personal, professional service, rapid response, and continuous product support--all at an affordable price so your project can be completed on time and within budget.

Typical Specs	10GHz	20GHz	40GHz
Insertion Loss	0.6 dB	0.8 dB	1.3 dB
Return Loss	22 dB	18 dB	15 dB



For technical assistance, custom product designs, or off-the-shelf delivery, call GGB Industries, Inc., at (239) 643-4400.

GGB INDUSTRIES, INC. • P.O. BOX 10958 • NAPLES, FL 34101
Telephone (239) 643-4400 • Fax (239) 643-4403 • E-mail email@ggb.com • www.picoprobe.com



DC TO 50 GHz

MMIC Amplifiers

300+ Models Designed in House

- Wide selection of GaAs HBT and E-pHEMT designs
- Noise figure as low as 0.38 dB
- OIP3 up to +50 dBm
- Industry-leading phase noise performance
- In-house packaging assembly
- Surface mount and bare die formats
- Upscreening available

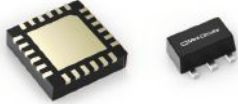


LEARN MORE



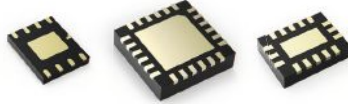
Options for Every Requirement

CATV (75Ω)



Supporting DOCSIS® 3.1 and 4.0 requirements

Dual Matched



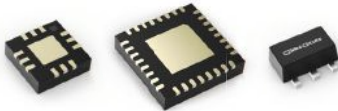
Save space in balanced and push-pull configurations

Hi-Rel



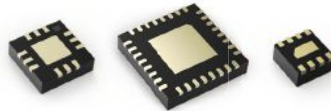
Rugged ceramic package meets MIL requirements for harsh operating conditions

High Linearity



High dynamic range over wide bandwidths up to 45 GHz

Low Noise



NF as low as 0.38 dB for sensitive receiver applications

Low Additive Phase Noise



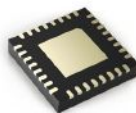
As low as -173 dBc/Hz @ 10 kHz offset

RF Transistors



<1 dB NF with footprints as small as 1.18 x 1.42mm

Variable Gain



Up to 31.5 dB digital gain control

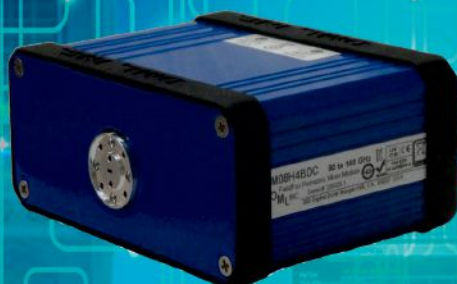
Wideband Gain Blocks



Flat gain for broadband and multi-band use

Portable Handheld Field Solutions

Expand your signal analysis capabilities
to 6G Research, Development & Deployment
90 GHz to 220 GHz and Beyond



M08H4BDC
90 GHz to 140 GHz



M06H6BDC
110 GHz to 170 GHz



M05H6BDC
140 GHz to 220 GHz

Innovation in Millimeter Wave Solutions
www.omlinc.com
(408) 779-2698



A soldier in camouflage gear is shown from the side, wearing a helmet with a mounted device and binoculars. He is holding a radio antenna mounted on a tripod. In the background, another soldier is visible, and the setting appears to be an outdoor field or airfield.

Take Control.

Partner with us to control the electromagnetic spectrum
in space, air, land, and sea.

Dominating the battlefield and protecting the warfighter begins with managing the electromagnetic spectrum. We combine proven reliability and performance with innovative new technology to design and build mission-ready components and subsystems. Learn more by visiting spectrumcontrol.com.



spectrumcontrol.com



5G

Outdoor Omnidirectional Antennas for 5G Networks

Our new selection of 5G, Outdoor-Rated Omni Antennas are designed for high reliability in extreme weather conditions and cover 4G, LTE, 5G, and CBRS bands.

These collinear omnidirectional antennas offer range extension and simple deployment to build out cellular communications networks as well as private networks. When you need broad coverage, but traditional base station antennas are too bulky or expensive, these 5G omni antennas are a perfect fit.

Place your order by 6 PM CT, and have your antennas or any other components shipped today.

pasternack.com
+1 (866) 727-8376
+1 (949) 261-1920

In-Stock and Shipped Same-Day



RF-LAMBDA
THE LEADER OF RF BROADBAND SOLUTIONS



BROADBAND SSPA / EMC BENCHTOP SOLID STATE POWER AMPLIFIER

**0.1-22GHz
ULTRA BROADBAND SSPA**

**RFLUPA01M22GA
4W 0.1-22GHz**



**RFLUPA0218GB
20W 1-19GHz**



300W 6-18GHz SOLID STATE BROADBAND



**400W 8-11GHz
SOLID STATE BROADBAND**

**0.1-6GHz VHZ,
UHF, L, S, C BAND**

**RFLUPA02G06GC
100W 2-6GHz**



**RFLUPA0706GD
30W 0.7-6GHz**



**MADE IN
USA**

6-18GHz C, X, KU BAND



**RFLUPA0618GD
60W 6-18GHz**



**RFLUPA08G11GA
50W 8-11GHz**

**RFLUPA06G12GB
25W 6-12GHz**

18-50GHz K, KA, V BAND



**RFLUPA18G47GC
2W 18-47GHz**



**RFLUPA27G34GB
15W 27-34GHz**



**RFLUPA47G53GA2
10W 47-53GHz**



**RFLUPA27G34GB
30W 18-40GHz**

BENCHTOP RF MICROWAVE SYSTEM POWER AMPLIFIER



RAMP06G06GA-30W 0.01-6GHz



RAMP39G48GA-4W 39-48GHz

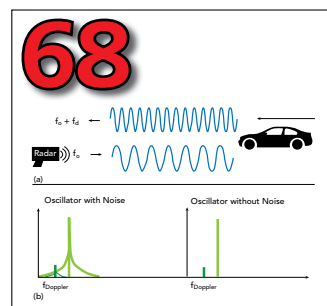
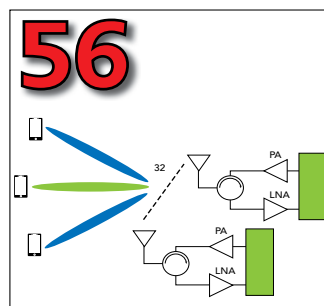
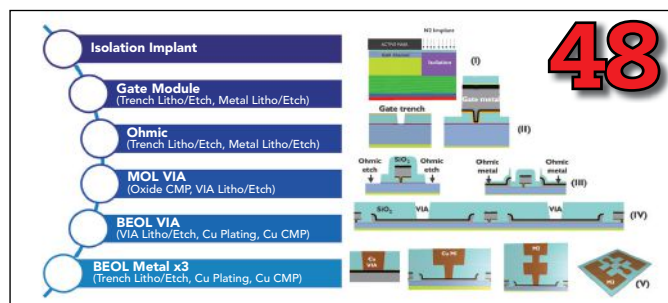


RAMP01G22GA-8W 1-22GHz



RAMP27G34GA-8W 27-34GHz

www.rflambda.com 1-888-976-8880 San Diego, CA, US Ottawa, ONT, Canada
sales@rflambda.com 1-972-767-5998 Carrollton, TX, US Frankfurt, Germany



Cover Feature

- 20** **Novel Design and Manufacturing Techniques Revitalize mmWave TWTs**
Diana Gamzina and Richard Kowalczyk, Elve, Inc.

Technical Features

- 48** **GaN-Based Devices for Advanced RF Applications Puts Technology Building Blocks in the Spotlight**
Bertrand Parvais and Hao Yu, imec

- 56** **RF SOI Enables 5G mMIMO Active Antenna Systems**
Payman Shanjani and Vikas Choudhary, pSemi Corporation

- 68** **The Importance of Crystal Oscillators With Low Phase Noise**
Julian Emmerich and Harald Rudolph, KVG Quartz Crystal Technology GmbH



online spotlight

Look for this month's exclusive article online at mwjournal.com

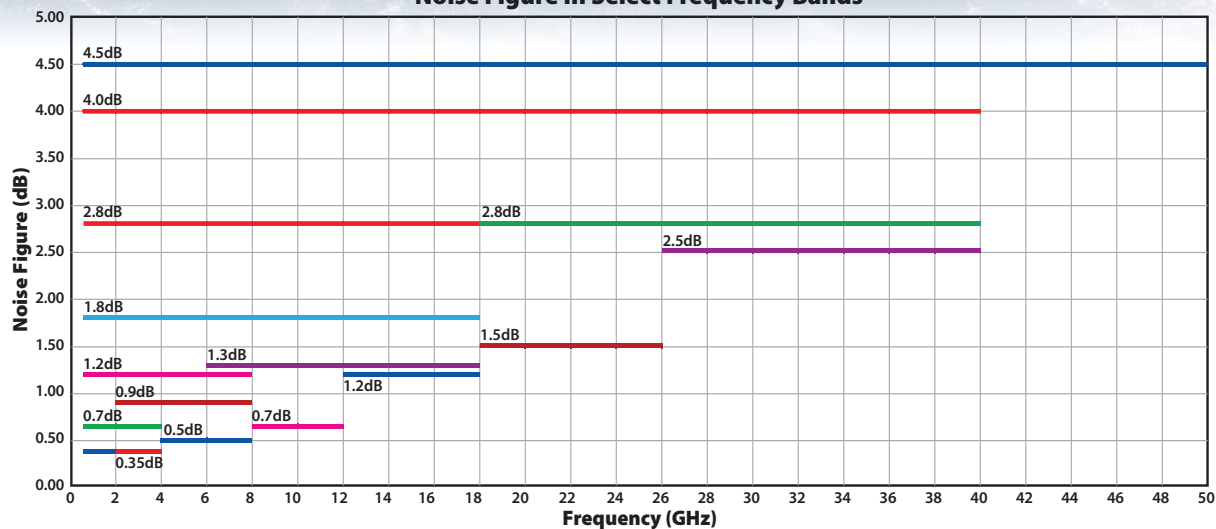
A Passive Wide Angle Retrodirective Array Based on Gain-Improved Microstrip Antenna and Phase Reversal Feed Between Elements

Jing Guo, XianQi Lin, YuXin Kang, ChangSong Liang and Delanyo Kulevome
University of Electronic Science and Technology of China

Has Amplifier Performance or Delivery Stalled Your Program?



Noise Figure In Select Frequency Bands



Microwave Journal

CONTENTS

mwjournal.com



Product Features

80 Using Drones to Verify Antenna Performance

QuadSAT

84 One Box Solution for FR1 Base Station, Small Cell and RF Component Test

Rohde & Schwarz

Tech Briefs

88 XFtd® Software Update Introduces Tuning Functionality for Comprehensive Matching Network Design

Remcom, Inc.

89 VNA Provides Component Analysis up to 26.5 GHz

SIGLENT Technologies

Departments

17	Mark Your Calendar	91	New Products
37	Defense News	94	Book End
41	Commercial Market	96	Ad Index
44	Around the Circuit	96	Sales Reps
90	Making Waves	98	Fabs & Labs

Microwave Journal (USPS 396-250) (ISSN 0192-6225) is published monthly by Horizon House Publications Inc., 685 Canton St., Norwood, MA 02062. Periodicals postage paid at Norwood, MA 02062 and additional mailing offices.

Photocopy Rights: Permission to photocopy for internal or personal use, or the internal or personal use of specific clients, is granted by Microwave Journal for users through Copyright Clearance Center provided that the base fee of \$5.00 per copy of the article, plus \$1.00 per page, is paid directly to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923 USA (978) 750-8400. For government and/or educational classroom use, the Copyright Clearance Center should be contacted. The rate for this use is 0.03 cents per page. Please specify ISSN 0192-6225 Microwave Journal International. Microwave Journal can also be purchased on 35 mm film from University Microfilms, Periodic Entry Department, 300 N. Zeeb Rd., Ann Arbor, MI 48106 (313) 761-4700. Reprints: For PDF reprints, contact Barbara Walsh at (781) 769-9750.

POSTMASTER: Send address corrections to Microwave Journal, PO Box 1028, Lowell, MA 01853 or e-mail mwj@e-circ.net. com. Subscription information: (978) 671-0446. This journal is issued without charge upon written request to qualified persons working in the RF & microwave industry. Other subscriptions are: domestic, \$130.00 per year, two-year subscriptions, \$200.00; foreign, \$225.00 per year, two-year subscriptions, \$400.00; back issues (if available) and single copies, \$20.00 domestic and \$30.00 foreign. Claims for missing issues must be filed within 90 days of date of issue for complimentary replacement.

©2023 by Horizon House Publications Inc.
Posted under Canadian international publications mail agreement #PM40612608

STAFF

Publisher: Carl Sheffres

Associate Publisher: Michael Hallman

Editorial Director: Patrick Hindle

Technical Editor: Eric Higham

Managing Editor: Jennifer DiMarco

Associate Technical Editor: Gary Lerude

Associate Technical Editor: Cliff Drubin

Editorial & Media Specialist: Kelley Roche

Associate Editor: Kaitlyn Joyner

Multimedia Staff Editor: Barbara Walsh

Electronic Marketing Manager: Chris Stanfa

Senior Digital Content Specialist: Lauren Tully

Digital Content Specialist: Vincent Carrabino

Audience Development Manager: Carol Spach

Director of Production & Distribution:

Edward Kiessling

Art Director: Janice Levenson

Graphic Designer: Ann Pierce

EUROPE

Office Manager: Nina Plesu

CORPORATE STAFF

CEO: William M. Bazy

President: Ivar Bazy

Vice President: Jared Bazy

EDITORIAL REVIEW BOARD

A. Chenakin	M. Roberg
B. Derat	U. Rohde
D. Jorgesen	F. Schindler
M. Ozalas	R. Smith
A. Poddar	D. Vye
C. Puente	W. Lohmeyer
B. Rautio	

EXECUTIVE EDITORIAL OFFICE

685 Canton Street, Norwood, MA 02062
Tel: (781) 769-9750
FAX: (781) 769-5037
e-mail: mwj@mwjournal.com

EUROPEAN EDITORIAL OFFICE

16 Sussex Street, London SW1V 4RW, England
Tel: Editorial: +44 207 596 8730 Sales: +44 207 596 8740
FAX: +44 207 596 8749

SUBSCRIPTION SERVICES

Send subscription inquiries and address changes to:
Tel: (978) 671-0446
e-mail: mwj@e-circ.net

www.mwjournal.com

Printed in the USA



From **Introduction** **to Production**

World-leading Manufacturers,
Value-added Services, and
Supply-chain Solutions.
That's RFMW.



RFMW has been the premier RF & Microwave and specialty distributor for 20 years. And now we're adding **Power Management** to our portfolio.

From introduction to production, **our team of experts** support your component selection, technical design and fulfillment needs.



**Amplifiers | Antennas | Attenuators | Beamformers | Cable Assemblies | Couplers
Combiners & Splitters | Diodes | Filters | Interconnect | Mixers | MMICs & RFICs
Resistors & Terminations | Switches | Test & Measurement | Transistors | Oscillators & Timing**

Order from the Experts
www.RFMW.com

**Sales@RFMW.com | Toll Free: +1-877-367-7369
188 Martinvale Lane, San Jose, CA 95119 U.S.A.**

LEARNING CENTER

Fully Integrated Ideal Switch Solution Meets PCIe 6.0 Requirements with HSIO Loopback

Sponsored by: RFMW and Menlo Micro

4/12

Mixed Technology Filters

Sponsored by: Knowles

4/13

Large Platform Co-site Interference Mitigation

Sponsored by: Altair

4/25



Catch Frequency Matters,
the industry update from
Microwave Journal,
microwavejournal.com/
FrequencyMatters

WHITE PAPERS



Large Platform Co-site Interference Mitigation

ALTUM RF

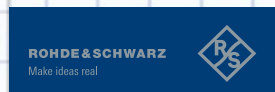
Cost-Effective Front-End Components for X- and Ku-Band Phased Array RADAR



Using Baluns and RF Components for Impedance Matching



Stop the Clock, How Advances in Quartz Crystals and Silicon Germanium BiCMOS Circuits Simplify High Speed Clock Generation for RF Data Converters

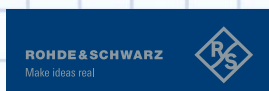


Understanding EMI Precompliance Testing



Holdover Plays an Important Role in the Network

Look for
additional content from:



Join Us Online

Follow us



@Pathindle

@MWJEric

@MWJEditor



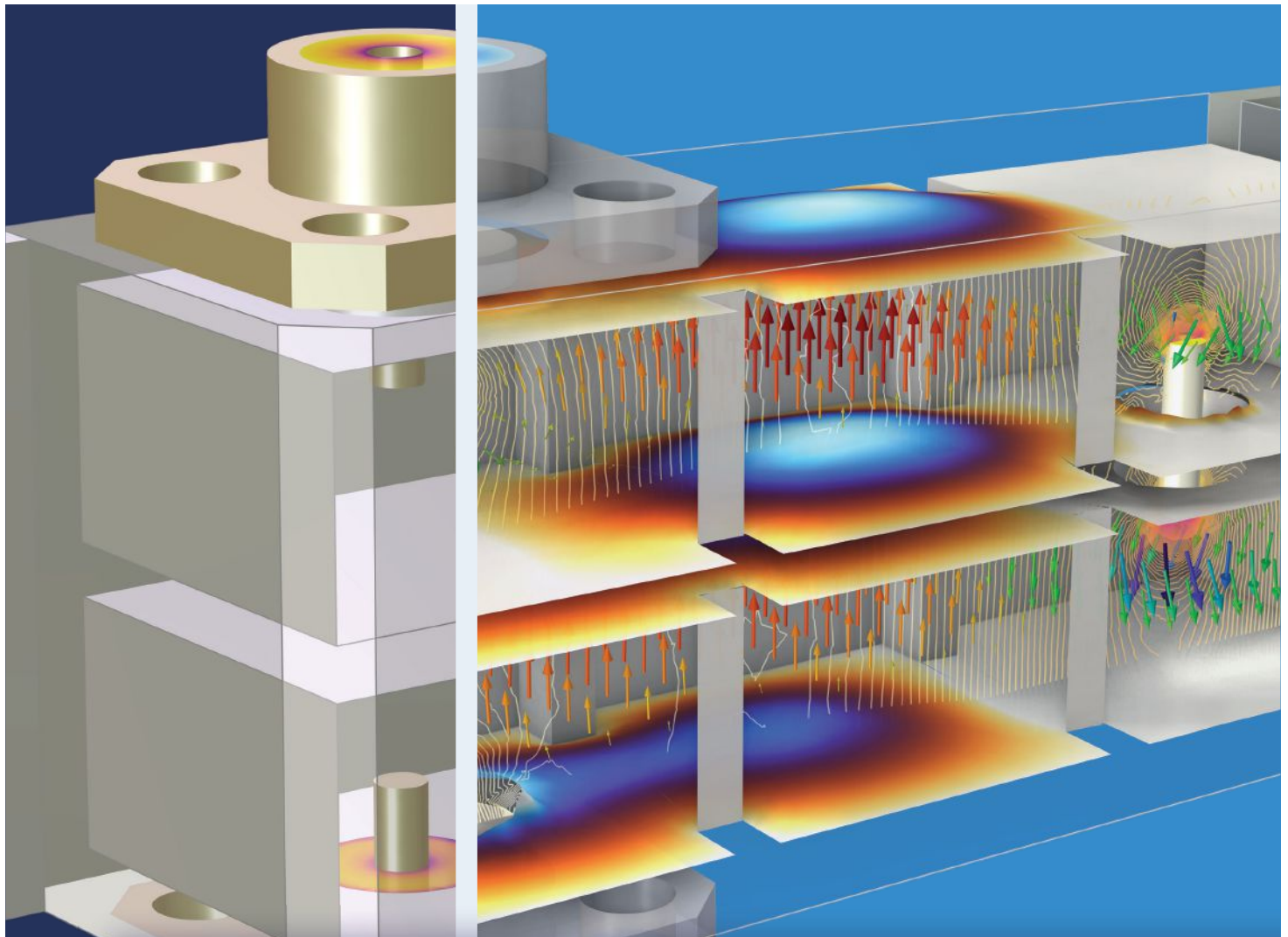
Join us at the RF and
Microwave Community



Become a fan at

[facebook.com/
microwavejournal](https://facebook.com/microwavejournal)

Visit us 
mwjournal.com

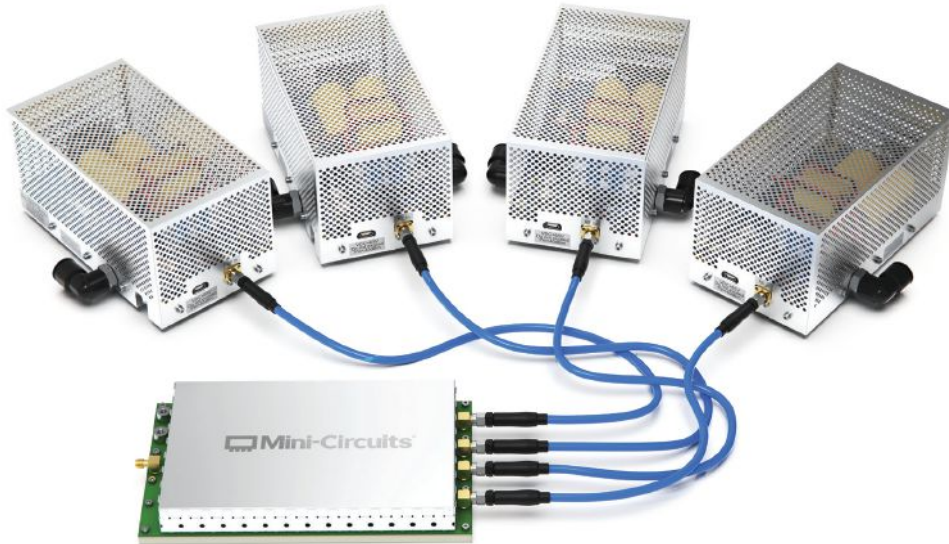


Take the Lead in RF Design

with COMSOL Multiphysics®

Multiphysics simulation is expanding the scope of RF analysis to higher frequencies and data rates. Accurate models of microwave, mmWave, and photonic designs are obtained by accounting for coupled physics effects, material property variation, and geometry deformation. Ultimately, this helps you more quickly see how a design will perform in the real world.

» comsol.com/feature/rf-innovation



ISM RF & MW ENERGY

27 MHz SSPA

Driver & Amplifier Pair from 1.7 to 6 kW

LEARN MORE



1.7kW Power Amplifier

RFE-24M30M1K7X+



- 1.7kW output power
- CW & pulsed signals
- 26 dB gain
- 80% efficiency
- Built-in temperature & current monitoring
- Built-in emergency switch off
- Water cooled

4-Channel Driver

RFE-24M30M075X+



- One input, four 19W outputs
- CW & pulsed signals
- 16 dB gain at P3dB
- 55% efficiency
- Integrated harmonic suppression
- Built-in temperature & current monitoring
- Built-in emergency switch off

 Mini-Circuits®



APRIL

17-18

WAMICON

Melbourne, Fla.

www.ieeeewamicon.org



19-20

IEEE Texas Symposium

Waco, Texas

<https://texassymposium.org>

MAY

2-4

Space Tech Expo USA

Long Beach, Calif.

www.spacetecheexpo.com



15-18

CS Mantech

Orlando, Fla.

<https://csmantech.org>



JUNE

5-6

Future Military Space USA

Los Angeles, Calif.

www.smgconferences.com/defence/northamerica/milspace-usa



11-16

IMS2023

San Diego, Calif.

<https://ims-ieee.org>



11-13

RFIC

San Diego, Calif.

<https://rfic-ieee.org>



16

ARFTG

San Diego, Calif.

www.arftg.org



20-23

Sensors Converge

Santa Clara, Calif.

www.sensorsconverge.com



21-22

MilSatCom USA

Arlington, Va.

www.smgconferences.com/defence/northamerica/conference/MilSatCom-USA



JULY

31-Aug 4

IEEE EMC + SIPI

Grand Rapids, Mich.

<https://emc2023.emcss.org>



Call for Papers
Deadlines

4/18

IEEE COMCAS

6/30

APMC 2023

7/7

IEEE HPEC

Online Panel

4/19

**Who Has the Highest Power
GaN Power Amplifiers?**



FOR DETAILS VISIT MWJOURNAL.COM/EVENTS

COMPLETE DC TO 330 GHz OFFERING
CUSTOM AT COMMERCIAL SPEEDS
OVER 5,000 MODELS AND COUNTING
MMW AND SUB-THz EXPERTS



ERA ∇ ANT
FORMERLY SAGE MILLIMETER



MAKING MMW ACCESSIBLE

MILLIMETER WAVE COMPONENTS & SUBASSEMBLIES

FROM DC TO 330 GHz

Eravant was founded in 2011 as SAGE Millimeter, Inc. by two veterans of the millimeter wave industry. Our company offers components, subsystems, and services from 18 to 330 GHz. Headquartered in Torrance, California with 60,000 square feet of engineering and manufacturing space, we supply the industry with custom and COTS solutions that can be scaled at volume. Heavy investment in product development continues to deliver first-to-market designs that enable customers working across all millimeter wave applications. Eravant is woman-owned, U.S.-owned, and ITAR-registered.



Scan the QR code to explore our
60,000 sq. ft. facility in Torrance, CA



Novel Design and Manufacturing Techniques Revitalize mmWave TWTs

Diana Gamzina and Richard Kowalczyk
Elve, Inc. Davis, Calif.

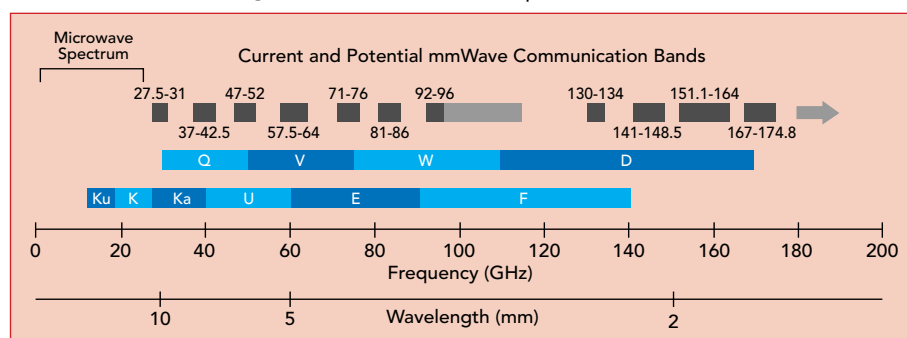
The mmWave spectrum offers many compelling advantages for communication applications. Compared to microwave systems, mmWave offers larger blocks of less contested and less regulated bandwidth for high data rates. The shorter wavelength allows reduced antenna size for a given antenna gain for compact systems. Compared to optical, mmWave losses in the atmosphere are modest and it is possible to “burn through” inclement weather to maintain a link. Additionally, with enough power the spot size at the receiver can be relatively large, providing tolerance for imperfect antenna pointing accuracy.

Wireless communications systems are finding increasing applications because of their reduced capital costs, ease of deployment and reduced environmental impact over physical carriers such as fiber. Wireless transmitters have long played an essential role in satellite communications (satcom) and are used terrestrially as point-to-point relays

to carry backbone traffic where the deployment of physical lines is difficult. Recently mmWave systems have seen rapid adoption for point-to-point terrestrial links up to W-Band and in satcom for gateway up-links up to V-Band. Access to bandwidth at these frequencies enables competitive data rates with those available over fiber optic cables. **Figure 1** shows the large swaths of frequency blocks available with the 71 to 76 GHz and 81 to 86 GHz bands each offering 5 GHz of continuous bandwidth. At W-Band, 92 to 114 GHz and at D-Band, 130 to 174.5 GHz, even larger bandwidths

are being considered for near-term network growth.¹ Future systems will operate at G-Band frequencies spanning 200 to 300 GHz ranges.²

The power amplifier (PA) is usually one of the last components in the RF chain before the antenna, playing a key role in system performance. Making use of mmWave for communications and imaging requires acquiring the signal at the receiver with a suitable signal-to-noise ratio. Practical systems that function over appreciable distances in various weather conditions often need tens of watts of power to meet requirements.



▲ Fig. 1 mmWave spectrum bands.

COAXIAL DIRECTIONAL COUPLERS

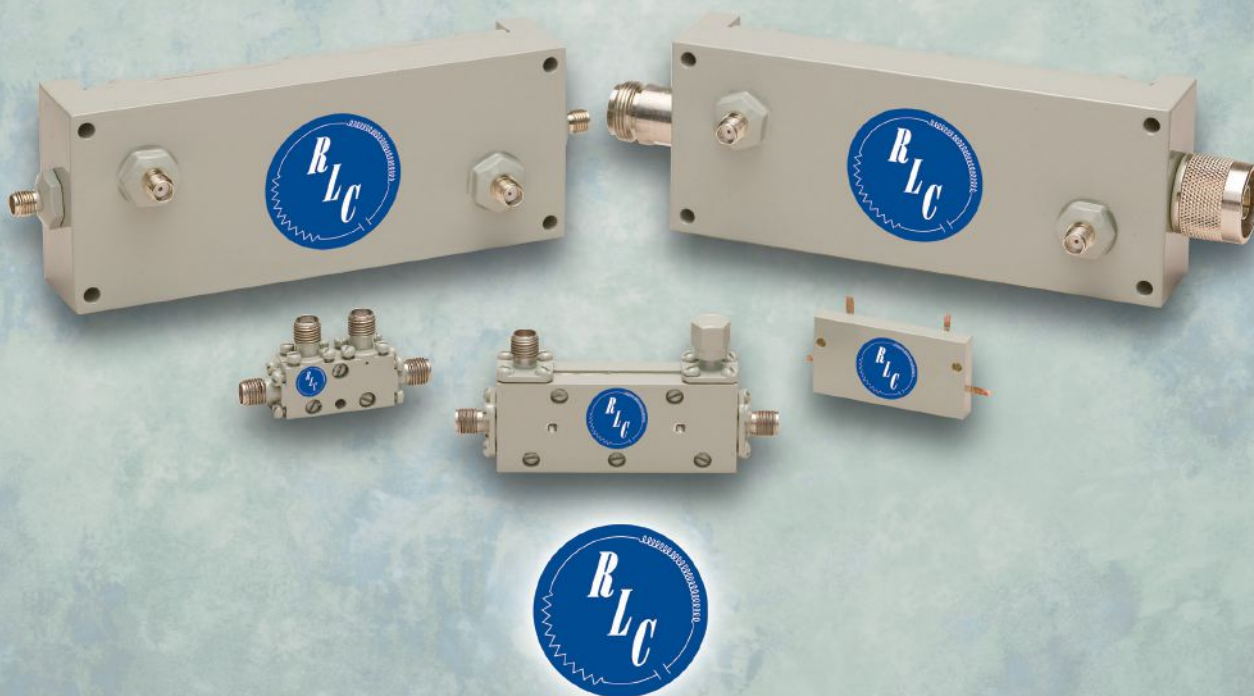
RLC has the exact solution you're looking for.

Our complete line of Directional Couplers covers cellular, octave and broadband frequencies.

Designs include micro-strip, stripline and airline for high power applications.

- Frequencies from 10 MHz to 40 GHz
- Power ratings up to 500 watts average
- Custom design & packaging
- Low loss, high directivity
- Single or dual directional
- Low coupling variation
- Surface mount
- Directional detectors
- Very low passive intermodulation designs
- Standard connector types
- Waveguide

For more detailed information on Directional Couplers and Directional Detectors, visit our web site.



RLC ELECTRONICS, INC.

83 Radio Circle, Mount Kisco, New York 10549 • Tel: 914.241.1334 • Fax: 914.241.1753

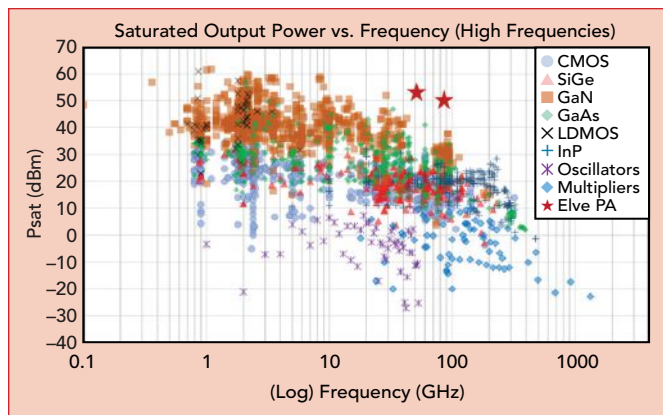
E-mail: sales@rlcelectronics.com • www.rlcelectronics.com

ISO 9001:2000 CERTIFIED

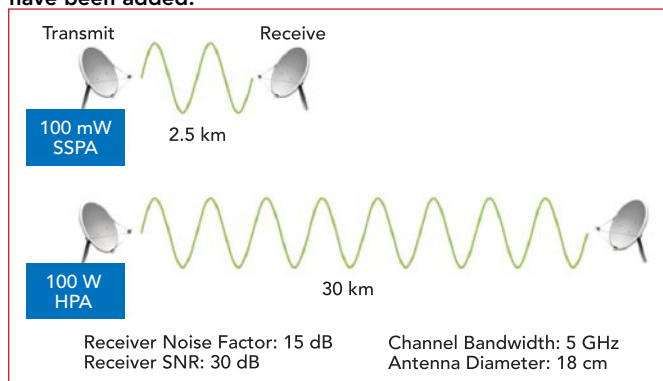
RLC is your complete microwave component source...

Switches, Filters, Power Dividers, Terminations, Attenuators, DC Blocks, Bias Tees & Detectors.





▲ **Fig. 2** Summary of available SSPAs.³ Elve power amplifiers have been added.



▲ **Fig. 3** Range enhancement with an E-Band TWT.

Achieving this at mmWave frequencies is a challenge. The advantages of mmWave systems have been acknowledged for decades, but the lack of availability of mmWave PAs has impacted mmWave deployment. Local heat dissipation limits achievable power in a single MMIC, so reaching watts of output power requires power combining that reduces efficiency. Low efficiency, low system-level power density, high thermal load and design complexity of mmWave solid-state power-combined systems are some of the challenges of deploying mmWave systems. While several technologies have been explored to deploy mmWave PAs,³ GaN and GaAs are the solid-state solutions that offer the most potential for high power levels as shown in **Figure 2**. New technologies offering increased power efficiently in compact forms are needed.

Traveling wave tube (TWT) amplifiers (TWTAs), consisting of a TWT and its power supply, or electronic power conditioner are a well-established highly reliable technology^{4,5} that has demonstrated high power efficiency in a compact form at mmWave frequencies. We believe that the technology outperforms solid-state power amplifiers (SSPAs), but is often overlooked for deployment in high data rate communications systems. As shown in **Figure 3**, a 100 W TWTA allows data to be transmitted at the same rate 10x as far as a 100 mW amplifier.

LINEAR BEAM AMPLIFIER OVERVIEW

Many vacuum devices are used to generate or amplify mmWave power. Linear beam devices, such as

klystrons, TWTs and backward wave oscillators (BWOs) provide power that is unachievable in solid-state devices. Klystrons are narrowband amplifiers with resonant circuits, producing high peak power. They are used in radar and some communication systems. TWTs employ a non-resonant circuit that allows significantly wider bandwidth, typically at lower power levels than klystrons. BWOs have a circuit that is designed for an unstable interaction with a backward traveling wave so the devices generate RF without an input signal, effectively amplifying noise.

THE TWT

TWTs are the vacuum amplifiers used most commonly in communication systems. Dr. Rudolf Kompfner is credited with the invention of the TWT,⁶ but Dr. John R. Pierce quickly realized the potential of the device to enable the type of communications he was working on at Bell Laboratories. He developed much of the engineering needed to design and build practical devices.⁷

TWTs amplify a signal using the kinetic energy carried by electrons traveling in a vacuum environment. The operation starts with an electron gun that creates an electron beam that is electrostatically focused into a narrow stream. Most TWTs employ a thermionic cathode, where a low work function material is heated to emit electrons into the vacuum. The hot cathode evaporates the emissive material, leading to a finite lifetime of electron emission. Electron energies are given by a Maxwellian distribution in the cathode and only those with energies above the cathode work function can travel into the vacuum. Higher electron emission requirements mean a hotter cathode for a given cathode material work function. A voltage applied to the anode accelerates the electrons and lenses electrostatically focus them into a compact beam. If the cathode surface is large and the focused beam small as in a high frequency TWT, this focusing may reduce the beam's cross-sectional area by a factor of a hundred, requiring extreme precision in the lenses.

Next, the electron beam, carrying kinetic energy established by the electrostatic acceleration, enters a magnetic field that counteracts the electrostatic repulsion of the electrons, maintaining a constant cross-section as the electrons travel through the interaction circuit. The circuit starts with an RF input port where power is injected. The RF is carried on a transmission line that wraps around the beam so that the electric field from the RF input power is aligned with the electron beam's axial motion. The alternating electric field speeds up some electrons and slows down others, forming electron bunches. As the modulated electron beam travels with the RF wave, the electron beam induces current on the circuit, causing the amplitude of the circuit wave to grow at the expense of the electron kinetic energy.

The electron beam and the electromagnetic wave must travel at similar speeds to form the electron bunches. Otherwise, the electron sees a sinusoidally-varying electric field with velocity increasing and decreasing, but on average retaining its initial energy. Electrons moving at a similar speed to the wave are continuously accelerated in the accelerating phase and

Solid State [of-the-Art] Switches

for mission-critical applications

- Designed for Industrial & Military Applications
- Broadband Frequency Coverage up to 70 GHz
- Low Insertion Loss, High Isolation & Fast Switching Speed,
- SPST-SP32T Designs, Reflective or Absorptive
- Connectorized or Surface Mount
- Form, Fit, Function & Custom Package Designs
- Hermetic Sealing
- Military or Aerospace Screening

Quantic PMI offers a full portfolio of RF and Microwave Solid State Switches that range from DC to 70 GHz.



Featured Products

P1T-DC52G-65-T-24FM

SPST Absorptive
Pin Diode Switch

P2T-100M56G-100-T

Absorptive, SP2T
Pin Diode Switch

P8T-100M54G-90-T-RD

Absorptive, SP8T
Pin Diode Switch

P16T-100M52G-100-T-DEC

Absorptive, SP16T
Pin Diode Switch

Frequency Range	DC-52 GHz	DC-56 GHz	DC-54 GHz	DC-52 GHz
Insertion Loss	8 dB @ 50 GHz	9 dB @ 52 GHz	9 dB @ 40 GHz	12.5 dB @ 40 GHz
Isolation	55 dB @ 50 GHz	100 dB @ 18 GHz	90 dB @ 40 GHz	80 dB @ 40 GHz
Switching Speed	15 ns	50 ns	50 ns	100 ns
Power Supply	+8 to +15 V @ 15 mA -8 to -15 V @ 40 mA	+5 V @ 100 mA -5 V @ 100 mA	+5 V @ 400 mA -5 V @ 300 mA	+5 V @ 1100 mA -12 V @ 720 mA
Configuration	SPST, Absorptive	SP2T, Absorptive	SP8T, Absorptive	SP16T, Absorptive
Dimensions (inches)	1.2" x 1.3" x 0.5"	1.0" x 0.75" x 0.4"	1.6" x 1.68" x 0.4"	8.0" x 3.0" x 0.77"
Connectors	2.4mm [F/M]	2.4mm [F]	2.4mm [F]	2.4mm [F]



Get a complete list of our solid state switch models and available options, download product features and other Switch Product technical data at quanticpmi.com

Or contact us at **1-877-752-6271** or sales@quanticpmi.com

continuously decelerated in the decelerating phase.

The amplified RF is coupled out at the end of the circuit and the spent electron beam goes to a collector. In most TWTs, the collector contains multiple electrodes, each depressed below ground to a different electric potential level. The electrons give up kinetic energy as they climb the potential hill created by these biased electrodes, allowing the power supply to recover energy, significantly improving the overall operating efficiency of the device. This energy recovery is one of the reasons that TWTs can achieve significantly higher efficiency than solid-state amplifiers.

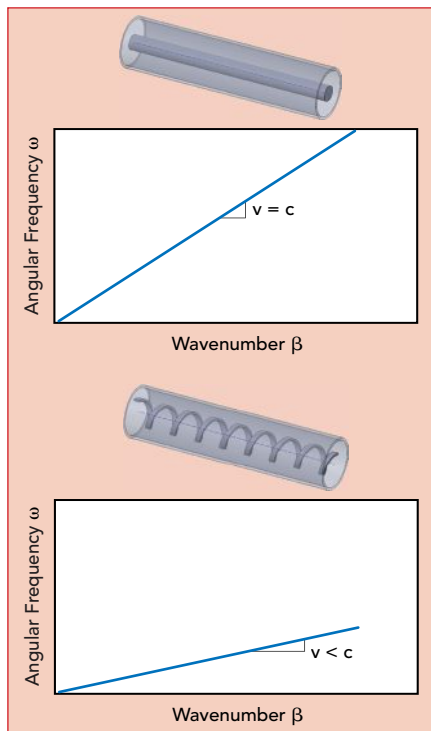
The technique of bunching the beam by adjusting electron velocity with an electromagnetic signal is commonly used in vacuum amplifiers. First demonstrated in klystrons in the 1930s, velocity modulation can produce high gain in the interaction circuit since small changes in velocity result in patterns of high and low current density downstream. Since all this happens in a collisionless vacuum environment, the approach allows these devices to scale to very high frequencies.

The most used TWT circuit is a helix, or more specifically a coaxial transmission line with the center conductor twisted into a helical path. The quasi-TEM mode on the transmission line follows the heli-

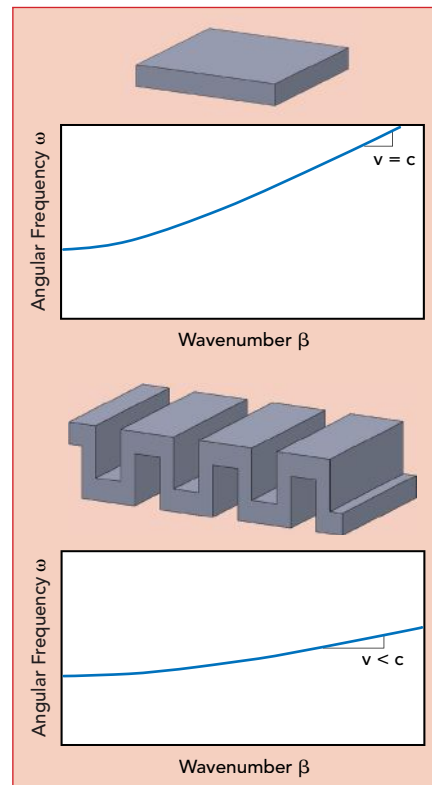
cal path, causing the axial velocity to slow. The electron beam travels through the center of the helical line where the electric field of the electromagnetic wave acts on the beam along the direction of the beam propagation.

On a coaxial line with a vacuum dielectric, the electromagnetic wave propagates at the speed of light. In a TWT, the helix pitch, the distance between each turn, reduc-

es the electromagnetic wave's net velocity in the beam direction. **Figure 4** shows this with a "dispersion curve," the relationship between frequency $\omega=2\pi f$ and wavelength. Frequency is plotted on the y-axis and inverse wavelength, called β on the x-axis. Since the velocity of a wave is given by frequency multiplied by wavelength, the velocity at



▲ **Fig. 4** Dispersion curves for coaxial line and helical delay line.



▲ **Fig. 5** Waveguide and folded-waveguide dispersion diagram.

AnaPico

of Switzerland

+41 44 440 00 50
rfsales@anapico.com
www.anapico.com

BNC
Berkeley Nucleonics

For US Customers:
800-234-7858
rfsales@berkeleynucleonics.com
www.berkeleynucleonics.com

ACCURATE RELIABLE AFFORDABLE

Phase Noise Analyzer

- 1 MHz to 7 / 26 / 40 / 50 / 65 GHz
- Input power range: -15 to +20 dBm
- Analysis range: 0.01 Hz to 100 MHz
- Transient analysis (16 ns time resolution)
- VCO characterization
- Time stability analysis (Allan deviation)
- Phase noise and amplitude noise measurement
- Absolute and additive noise measurement
- CW and pulsed signals (50 ns pulse width)



RF-LAMBDA

MADE IN USA



THE LEADER OF RF BROADBAND SOLUTIONS

EMC Broadband RF Power Amplifier High Power Solid State



FREQUENCY UP TO 90GHZ

POWER UP TO 2KW CW

REMC06G18GG

6-18GHZ 300W

- AUTOMATIC BUILT IN SELF CALIBRATION AND BIAS ADJUSTMENT.
- OVER TEMPERATURE, CURRENT, INPUT POWER PROTECTION.
- VSWR MEASUREMENT AND OPEN CIRCUIT PROTECTION.
- USER FRIENDLY CONTROL INTERFACE.
- REMOTE ETHERNET CONTROL AND FIRMWARE UPDATE.
- HIGH POWER EFFICIENCY AND LIGHTWEIGHT.



RAMP42G47GA 42-47GHZ 8W



RAMP18G40GB-U 18-40G 20W



RAMP05M80GC 0.5-80GHZ

REMC02G06GE 2-6GHZ 500W



REMC08G11GE 8-11GHZ 400W



any point on the curve is ω/β .

TWT circuits based on two-conductor transmission lines can be extremely wideband since they use the TEM mode, which has no cutoff frequency. Unfortunately, the center conductor must be electrically isolated from the outer conductor. This requires ceramics to support the helix, resulting in non-ideal heat paths for electrons that intercept the circuit and ohmic losses generated in the helix. For applications requiring smaller bandwidths, single-conductor transmission line circuits are preferable. These circuits can be all metal, improving thermal power handling. Many traditional TWTs are made from coupled cavities that use a series of resonant cavities connected with irises or slots to create a winding RF path.

A folded-waveguide circuit employs a waveguide bent back on itself many times, reducing the effective speed of the RF along the beam propagation.⁸ A beam tunnel hole is punched through the circuit. Starting with the dispersion curve of the

waveguide, the net velocity of the RF following the waveguide path is reduced as shown in **Figure 5**.

The periodic structure results in a periodic dispersion curve shown in **Figure 6**. The direction of the electric fields reverses each time the waveguide folds back on itself. As the electron beam passes through the folded-waveguide structure, it sees an additional 180-degree phase shift every half period as shown in **Figure 7**.

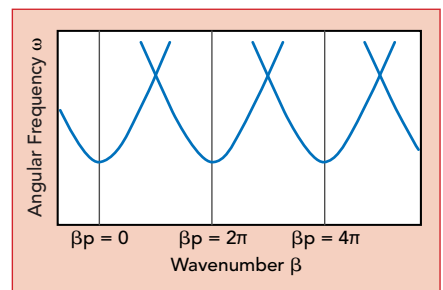
Figure 8 shows the resulting dispersion curve. Appropriate values of waveguide cross-section and path can be chosen to achieve a phase velocity that matches the beam velocity. The circuit can be optimized for a relatively constant phase velocity over the band, resulting in flat gain over frequency for a wideband amplifier.

MMWAVE TWTs

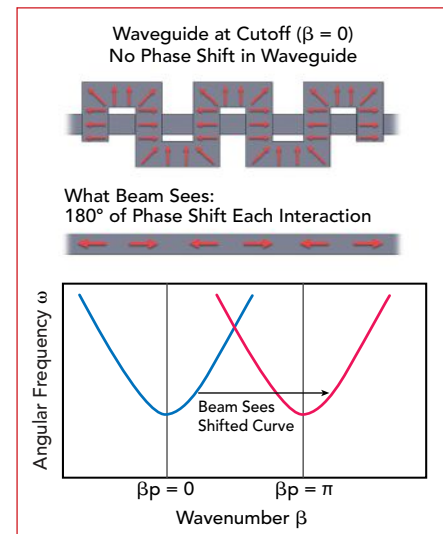
Many TWTs using helix circuit designs to generate hundreds of watts of power at Ka-Band for communications systems are available

today. Suppliers include Stellant, CPI, Thales, Photonis, Teledyne and NEC. These TWTs can have efficiencies over 50 percent with output power densities around 100 mW/cm³.

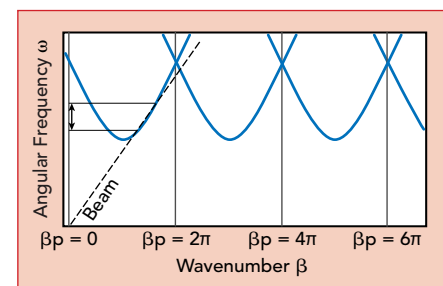
For applications where size or weight are at a premium, mini-TWTs are often used. These devices have shorter circuits and reduced gain that is offset by higher-power solid-state drivers. Lower voltages allow for a very compact high-voltage power supply to be packaged with the TWT. At Ka-Band, up to 100 W is available with power densi-



▲ **Fig. 6** Folded-waveguide periodic dispersion curve.



▲ **Fig. 7** Folded waveguide field as seen by electron beam.



▲ **Fig. 8** Dispersion curve for folded-waveguide TWT interacting with an electron beam.

Covering Your Spectrum

- Fixed Attenuators
- Variable Attenuators
- Terminations
- Power Dividers/Splitters
- RF Adapters
- DC Blocks
- RF Tuners
- DC to 50 GHz
- 1 Watt to 2000 Watts
- Custom Solutions

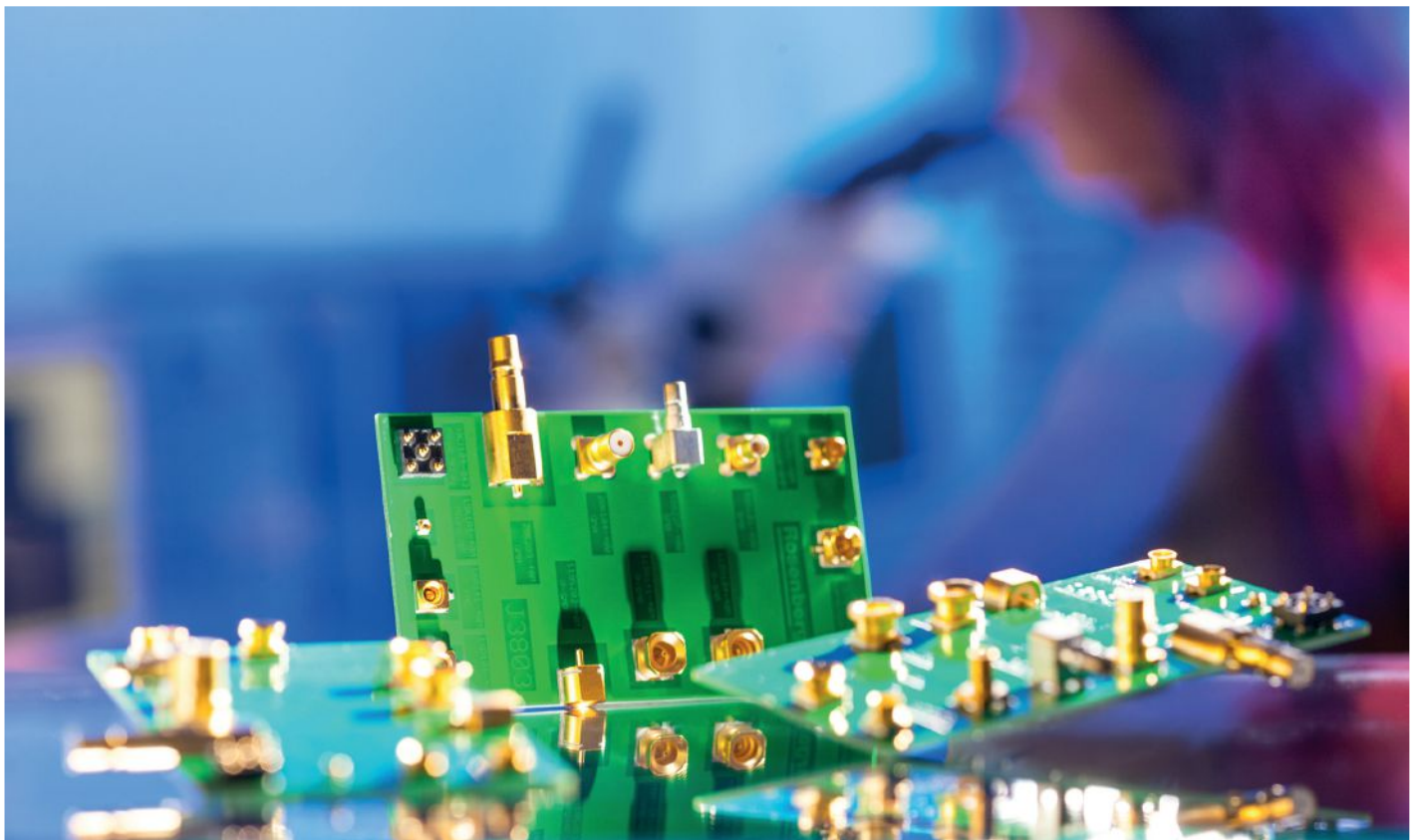
Providing the highest quality and cost-competitive
Broadband RF and Microwave Products
in the Industry since 1989.

Visit our new website with interactive catalog and online RFQ!

www.WeinschelAssociates.com

2505 Back Acre Circle
Mount Airy, MD 21771
Voice: 301.963.4630
Fax: 301.963.8640
sales@WeinschelAssociates.com

WEINSCHEL ASSOCIATES
BROADBAND RF & MICROWAVE SOLUTIONS



SURFACE MOUNT TECHNOLOGY

PCB Connectors

Rosenberger provides a wide range of RF coaxial connectors for PCB applications – for board-to-board- and also for cable-to-board connections.

Whether well-established standard connector series or newly developed innovative connectors – Rosenberger PCB connectors feature a lot of customer benefits:

- Minimum board-to-board distances
- Radial and axial misalignment using bullets
- Space-saving and cost-effective assembly design
- Excellent transmission quality
- Variety of back end types, e.g. SMT, edge mount, pin-in-paste, solder pin, solderless connectors as well as bullets

www.rosenberger.com



Rosenberger

	Elve	SSPA A	SSPA B	SSPA C	MPM
Frequency	81-86 GHz	81-86 GHz	81-86 GHz	81-86 GHz	81-86 GHz
Power	100 W sat	5 W sat	2.5 W sat	4 W sat	200 W sat
Size	23 x 15 x 8 cm	9 x 15 x 15 cm	12 x 13 x 9 cm	11 x 10 x 5 cm	38 x 27 x 8 cm
Power Density	37 mW/cm ³	2 mW/cm ³	2 mW/cm ³	7 mW/cm ³	26 mW/cm ³
Efficiency	32%	3%	5%	6%	30%

▲ Fig. 9 Comparison of E-Band amplifiers.

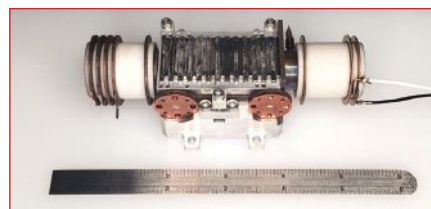
ties of hundreds of mW/cm³. At E-Band frequencies there are fewer commercially available options, as shown in **Figure 9**.

ELVE TWTs

The construction of vacuum electronic devices, such as TWTs, is often an artisan process; it requires extremely high-precision machining and assembly. The tolerances become more exacting as the frequency increases. Each mmWave circuit is constructed and assembled individually and can take months to complete. Fabrication techniques for the circuit include micromachining (milling or EDM) as well as electroplating around LIGA molded

photoresist, etched silicon or 3D-printed polymer structures.^{9,10,11,12} These processes do not easily accommodate design changes to individual circuits with minimal process adjustments. The processes used to date have significant limitations in the rate of production.

Elve has developed TWT design and fabrication techniques suitable for making mmWave TWTs in volume. The TWTs employ nanocomposite scandate tungsten emitters, which have a significantly lower work function than traditional TWT emitter materials. These special materials allow the emitted electron current density to be higher for the same temperature. As a result,



▲ Fig. 10 Elve E-Band TWT.

a smaller emitter can be employed enabling the devices to be robust to minor dimensional errors in the beam-focusing structures while maintaining a long lifetime.

Elve TWTs use a “sheet” beam with an elliptical, rather than round, cross-section of the electron beam perpendicular to the direction of travel. The elliptical geometry reduces space charge density and power density in the beam, reducing the magnetic field requirements to confine the beam. Maintaining one of the ellipse dimensions small relative to wavelength enables good circuit efficiency, the ratio at which electron beam kinetic energy is converted into RF energy. The planar sheet beam configuration is well-suited for modern manufacturing techniques.

Elve has developed an additive manufacturing technique to fabricate the circuits. Using this approach, circuits of different frequencies can easily be fabricated using the same process. Other devices that interact with electron beams, like klystrons or gyrotrons, can be made with this approach. The circuit technology is critical to Elve’s ability to rapidly iterate TWT designs. In production, it allows circuits and TWTs to be made quickly and consistently at volume. The compact planar design of an Elve TWT is shown in **Figure 10**.

Traditional microwave TWTs have demonstrated decades of reliable operation in space applications. Elve is designing and testing amplifiers to meet the same rigorous standards. The cathodes are the most sensitive portion of the TWT, so samples from each batch of powder are tested to verify the work function and emitted current. Elve is putting complete units through environmental testing including cathode heater cycling, operational on/off cycling, vibration testing and operation at temperature extremes

LB5940A Power Sensor With Option SPI & I2C



- Thermally stable, no drift or user zeroing
- Interface with micro-controllers & FPGA's
- Development hardware available at no cost
- Command testing with USB & Interactive IO
- -60 to +26 dBm & first tier NIST traceable

LadyBug
Fast, Accurate, Traceable

Since 2004
Boise, ID, USA
707-546-1050
LadyBug-tech.com



Ka-Band Power

27 TO
31 GHz

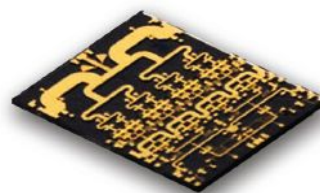
Maximized performance for
linear power applications

GaN MMIC's to 40W

Nxbeam's suite of Ka-band PA MMICs offers customers an unparalleled combination of power, gain, and efficiency with proven reliability.

PRODUCTS:

NPA2001-DE
NPA2002-DE
NPA2003-DE
NPA2030-DE



Packaged MMICs to 35W

Nxbeam offers its Ka-band MMICs in leaded flange packages for easier system integration

PRODUCTS:

NPA2001-FL
NPA2002-FL
NPA2003-FL
NPA2030-FL



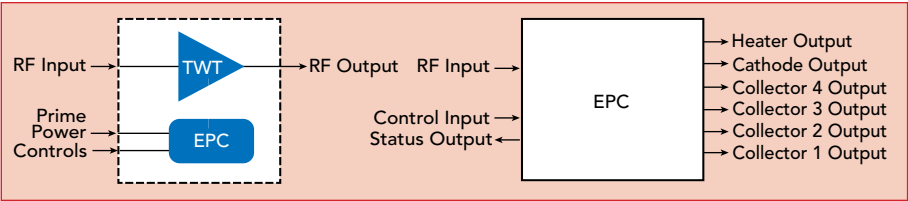
Module Products to 60W

For higher levels of power and integration, Nxbeam offers modules that combine multiple Nxbeam MMICs to achieve higher performance in an easy-to-use form factor. Custom designs available

PRODUCTS:

NPM2001-KW
NPM2002-KW
NPM2003-KW





▲ Fig. 11 EPC powering the TWT heater, cathode and collectors.

TABLE 1	
E-BAND AMPLIFIER RF PERFORMANCE SUMMARY	
Parameter	Result
Frequency	81 to 86 GHz
RF Output Power	100 W minimum
RF Input Power	34 dBm maximum saturation
Duty Cycle	CW
AM/PM Conversion	3°/dB maximum
RF Input/Output	WR-12



▲ Fig. 12 Elve E-Band PA including TWT and EPC.

to identify and resolve any potential reliability issues.

A complete TWT-based amplifier contains an electronic power conditioner (EPC) shown in **Figure 11**, which produces the operating voltages for the TWT. A compact TWT requires a negative cathode voltage of several kilovolts, typically in the range of -3 to -20 kV. The cathode voltage must be tightly regulated with extremely low ripple to enable ideal RF performance from the TWT. The cathode heater, floating at cathode potential, requires a few watts of power. The multi-stage depressed collector is biased with voltages between cathode potential and ground to enable efficient recovery of spent electron beam energy. In addition to generating the TWT electrode voltages, an EPC also provides the control logic and user interface to allow system integration.

The Elve Vermillion E-Band amplifier shown in **Figure 12** covers 81 to 86 GHz. The amplifier has a small

signal gain of 20 dB, with other parameters shown in **Table 1**. Transfer curves are shown in **Figure 13** with simulated linearity performance shown in **Figure 14**.

The behavior under multi-tone input waveforms is shown in **Figure 15**. When driven by 30 dBm input power per carrier to produce more than 100 W of total output power, split between two carrier frequencies, third-order intermodulation distortion is around 16 dB.

There have been impressive mmWave and THz TWT results reported by Stellant^{13,14} and Northrop,¹⁵ demonstrating a technological path to mmWave vacuum power devices. The volume has been low, but Elve has spent the past 18 months developing a high volume TWT fabrication process. Elve's process is evolving with early prototype amplifiers providing feedback to improve subsequent units. Prototype gain performance is shown in **Figure 16** with temperature performance shown in **Figure 17**.

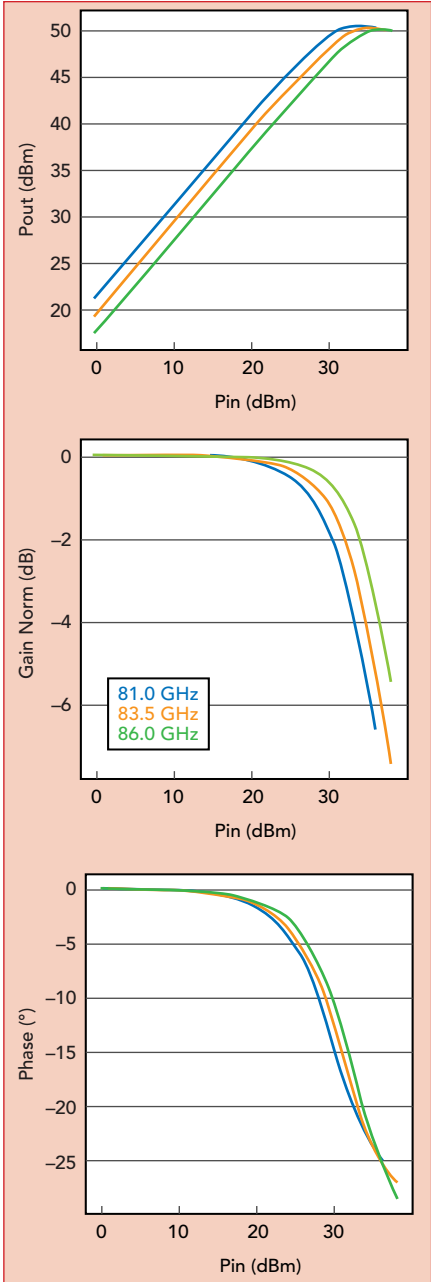
CONCLUSION

TWTs have been a workhorse in communications, radar and imaging applications. They have an opportunity to return to the spotlight and showcase unprecedented performance at mmWave frequencies. Decades of demonstrated reliability, high power and efficiency are some of the advantages TWTs offer. Elve's focus on large-quantity manufacturability ensures access to TWT

advantages to enable the next generation of connectivity. ■

References:

1. Ericsson Microwave Outlook Report, October 2022, Web: <https://www.ericsson.com/en/reports-and-papers/microwave-outlook>.
2. "DARPA Asks Industry to Develop G-Band RF and Microwave Enabling Technologies for Communications and Sensing," Web: <https://www.militaryaerospace.com/rf-analog/article/14211440/rf-and-microwave-gband-communications-and-sensing>.
3. H. Wang, T. Y. Huang, N. Sasikanth Manem, J. Lee, E. Garay, D. Munzer, E. Liu, Y. Liu, B. Lin, M. Eleraky, H. Jalili, J. Park, S. Li, F. Wang, A. S. Ahmed, C. Snyder, S.



▲ Fig. 13 Simulated RF transfer characteristics.

ALTUM RF

**SEE US AT
IMS2023**

BOOTH 1648



Q, V & E-band
37-57 GHz, 57-71 GHz &
71-86 GHz amplifiers

**RANGE OF
RF PRODUCTS**

27-31.5 GHz Ka-Band GaN PAs
9-11 GHz X-Band GaN PAs
2-20 GHz GaN PAs

**SERVING
NEXT-GEN MARKETS
& APPLICATIONS**

with proven GaAs and GaN
technologies and decades of
design expertise

**5G
TELECOM**

Ka-band
E-band

FIND US NOW



Contact Altum RF
and our sales and
distribution partners

DISCOVER ALTUM RF

Altum RF designs high-performance RF to millimeter-wave solutions for commercial and industrial applications. Using proven technologies like GaAs and GaN, Altum RF products deliver optimized RF performance, integration levels and costs.

LEARN MORE AT [ALTUMRF.COM](https://altumrf.com)

info@altumrf.com | +31 (0) 40 2390 888 |

©2023 Altum RF. All rights reserved.

Twinning Center, De Zaale 11,

5612 AJ Eindhoven, The Netherlands

800.348.5580 / 630.208.2200

RELLPOWER@RELL.COM

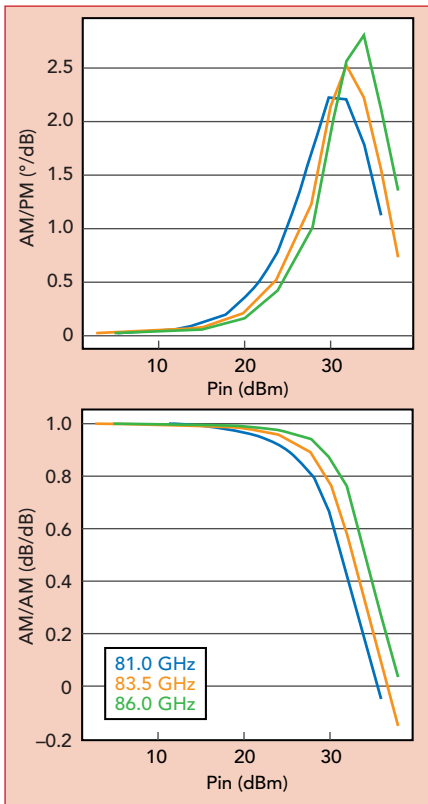
[RELLPOWER.COM](https://rellpower.com)

**Richardson
Electronics**
POWER & MICROWAVE
TECHNOLOGIES

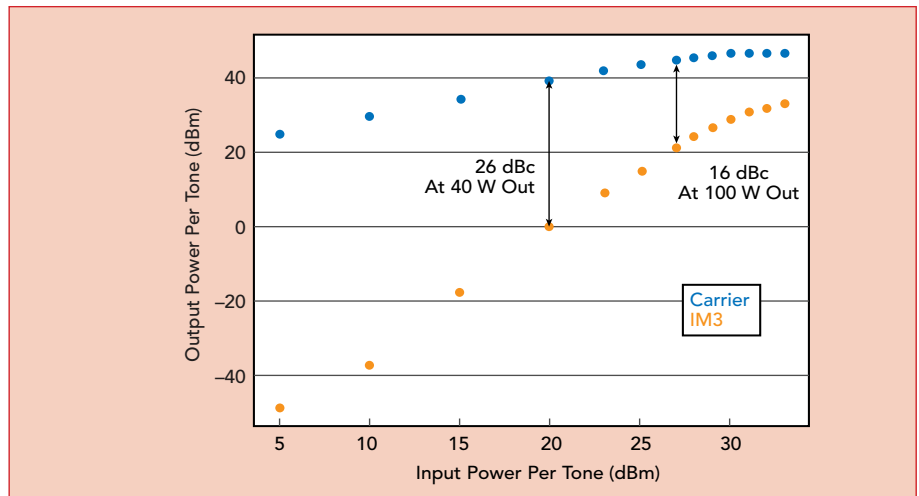
Visit Richardson Electronics, Ltd. at booth 1216 at IMS2023

40W267 Keslinger Road / P.O. Box 393
LaFox, IL 60147-0393

Copyright © 2023 Richardson Electronics, Ltd. All rights reserved.



▲ Fig. 14 Simulated linearity characteristics.



▲ Fig. 15 Two-tone intermodulation distortion at band center.

- Lee, H. Thong Nguyen and M. E. Duffy Smith, "Power Amplifiers Performance Survey 2000-Present," Web: https://gems.ece.gatech.edu/PA_survey.html.
- NASA Spinoff, Traveling-Wave Tubes Travel Far, Web: <https://spinoff.nasa.gov/Traveling-Wave-Tubes-Travel-Far>.
 - R. Ludwig and J. Taylor, "Descanso Design and Performance Summary Series Article 4: Voyager Telecommunications," Washington: NASA (2002): 1–6.
 - R. Kompfner, "The Invention of the Traveling-wave Tube," San Francisco Press, 1964.
 - J. R. Pierce, "Traveling-wave tubes," *The Bell System Technical Journal* 29, No. 2, 1950, pp. 189–250.
 - R. GE, Hutter and S. W. Harrison, "Beam and Wave Electronics in Microwave Tubes," van Nostrand, 1960.
 - R. L. Jaynes, A. M. Cook, C. D. Joye, J. C. Rodgers, A. N. Vlasov, I. A. Chernyavskiy, J.P. Calame et al, "Microfabrication and Micromachining for Millimeter-Wave Traveling Wave Tubes," 2020 IEEE International Conference on Plasma Science



www.swiftbridgetechnologies.com



◀ SCAN ME
Link to Digi-Key
where FastEdge
products are sold

FastEdge™ RF CABLE ASSEMBLIES

Swift Bridge Technologies, a global provider of custom cable solutions for the test and measurement market, is proud to announce the launch of the all new FastEdge™ RF product line on the Digi-Key marketplace. The FastEdge™ RF product line is a general-purpose, versatile, and economic RF cable solution for a variety of test environments and suitable for a broad range of instruments.

Delivering operational frequencies of up to 40 GHz, these RF test cables are available with various connector types including high performance SMA, Right Angle SMA, and 2.92mm connectors. The FastEdge™ RF product line eliminates the need for RF adapters, which would otherwise introduce additional and unnecessary signal loss. The FastEdge™ RF product line is designed to be used in a variety of test environments, and suitable for a broad range of uses including:

- Clock Timing
- Compliance Testing
- Wireless Communication
- Probing
- Multiplexing
- Signal Routing

Swift Bridge Technologies is pleased to offer the FastEdge™ RF product line in standard lengths of 0.5 meter and 1 meter as well as custom lengths upon request.

FastEdge™ RF cable assemblies are general-purpose, versatile, and economic RF cable solutions. Some advantages of FastEdge™ RF cables include:

- Low attenuation and low VSWR
- Amplitude and phase stable with flexure
- Suitable for spectrum analyzers, network analyzers, signal generators, oscilloscopes, production test sets
- Molded flex reliefs distribute cable stresses away from the connector and prevent excessive bending of the cable
- Suitable for 125°C continuous use





*Your Preferred Microwave and mmWave
modules Supplier, DC-220GHz*

***Need Super-Broadband Amplifier modules?
We have them in stock.***

www.atmicrowave.com

- ✓ Frequency 10MHz to 26.5/43.5/50/70GHz
- ✓ Gain from 10 to 60dB
- ✓ Output Power from 0dBm to +33dBm
- ✓ SMA, 2.92mm, 2.4mm and 1.85mm

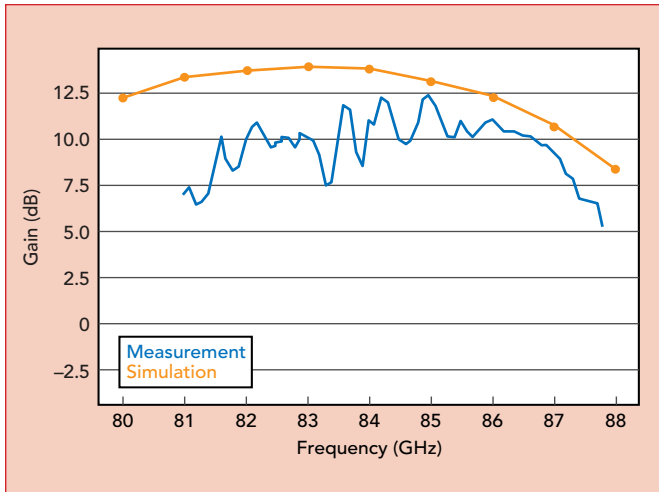


Shanghai AT Microwave Limited

Tel: +86-21-6229 1233

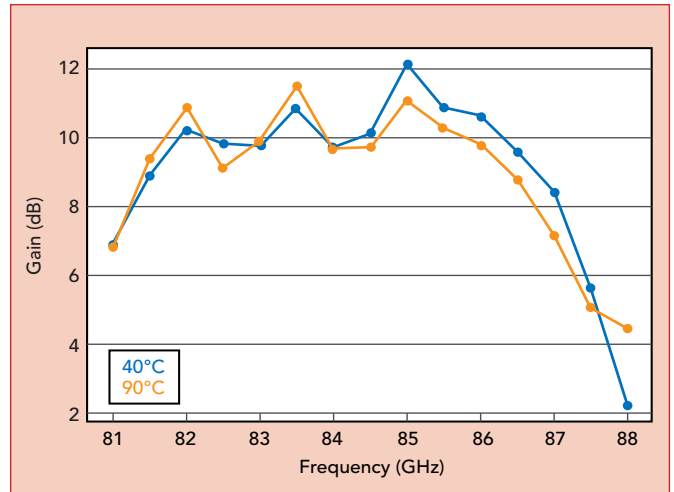
Email: sales@atmicrowave.com

www.atmicrowave.com



▲ **Fig. 16** Simulated and measured data for an early Elve prototype TWT.

- (ICOPS), pp. 316–316, 2020.
10. A. Baig, D. Gamzina, M. Johnson, C. W. Domier, A. Spear, L. R. Barnett, N. C. Luhmann and Y.-M. Shin, "Experimental Characterization of LIGA Fabricated 0.22 THz TWT Circuits," *2011 IEEE International Vacuum Electronics Conference (IVEC)*, 2011, pp. 275–276.
 11. J. C. Tucek, M. A. Basten, D. A. Gallagher, K. E. Kreischer, R. Lai, V. Radisic, K. Leong and R. Mihailovich, "A 100 mW, 0.670 THz Power Module," *IVEC*, 2012, pp. 31–32.
 12. A. M. Cook, C. D. Joye and J. P. Calame, "W-band and D-band Traveling-wave Tube Circuits Fabricated by 3D Printing," *IEEE Access* 7, 2019, pp. 72561–72566.



▲ **Fig. 17** TWT temperature performance.

13. R. Kowalczyk, A. Zubyk, C. Meadows, T. Schoemehl, R. True, M. Martin, M. Kirshner and C. Armstrong, "High Efficiency E-band MPM for Communications Applications," *IVEC*, 2016, pp. 1–2.
14. N. Robbins, D. Eze, H. Cohen, X. Zhai, W. McGeary, W. Menninger, M. Chen and E. Rodgers, "Space Qualified 200-Watt Q-band Linearized Traveling-wave Tube Amplifier," *IVEC*, 2018, pp. 13–14.
15. Jack C. Tucek, M. A. Basten, D. A. Gallagher and K. E. Kreischer, "Operation of a Compact 1.03 THz Power Amplifier," *IVEC*, 2016, pp. 1–2.
16. W. L. Menninger, T. K. Phelps and J. Lingenfelter, "4.2: Performance and Reliability of Recent Production Space Linearized Traveling-wave Tube Amplifiers," *IVEC*, 2010, pp. 49–50.



Communications
& Power Industries

Amplifiers for EMC Testing - Long life and Durable



CPI celebrates

75

TH
ANNIVERSARY



CPI provides a complete line of high-powered continuous wave (CW) and pulsed instrumentation amplifiers for EMC testing

Key Features & Benefits

- Output power up to 40 kW
- Frequencies from L-Band to Ka-Band
- Versatile
- Easy to maintain
- User-friendly



Contact the pulsed instrumentation amplifier experts at CPI: ElectronDevices@cpii.com

Communications & Power Industries • TMD Technologies Division • Unit 3 Swallowfield Way, Hayes, Middlesex, UK, UB3 1DQ
+44 (0)20 8573 5555 • www.cpii.com



LOW NOISE AMPLIFIERS

**The Leader in Amplifier Technology
With The Lowest Noise Figures in The Industry**

- DC to 40 GHz Low Noise Coaxial Amplifiers
- Ultra Low Noise Single Bias Cryogenic Amplifiers
- Space Qualified Low Noise Amplifiers
- S, C, X, Ku, Ka Band Waveguide Amplifiers
- SATCOM Amplifiers
- Wideband Amplifiers
- Medium Power Amplifiers
- Multioctave Amplifiers
- Surface Mount Amplifiers
- Desktop Amplifiers
- Custom Amplifiers



Low Noise Amplifiers								
Part Number	Frequency (GHz)	Gain (dB)	G.F. (dB)	N.F. (dB)	I/O VSWR	P@1dB (dBm)	V (V)	I (mA)
APT6-02200240-0515-D44	2.2-2.4	60	±0.5	0.3	1.3:1/1.5:1	+15	+15	300
APT4-07250775-0710-D6	7.25-7.75	30	±0.5	0.4	1.5:1/1.5:1	+10	+15	100
APT4-10951275-0810-D6	10.95-12.75	35	±1.0	0.7	1.5:1/1.5:1	+10	+15	100
APT22-12001800-1515-D22	12.0-18	45	±2.0	1.2	2.0:1/2.0:1	+15	+15	300
APT4-18004000-3005-D20	18-40	45	±3.0	2.7	2.5:1/2.5:1	+5	+15	250



SATCOM Amplifiers								
Part Number	Frequency (GHz)	Gain (dB)	G.F. (dB)	N.T. (K)	I/O VSWR	P@1dB (dBm)	V (V)	I (mA)
APTW5-07100840-35K10-WR112D6	7.10-8.40	50	±1.0	35	1.5:1/1.5:1	10	+15	200
APTW5-10951275-40K15-WR75D6	10.95-12.75	50	±0.5	35	1.5:1/1.5:1	15	+15	200
APTW5-17702120-100K10-WR42D22	17.3-22.0	50	±1.0	85	1.3:1/2.0:1	10	+15	175
APTW5-19251940-82K20-WR42D22	19.25-19.40	45	±0.5	70	1.3:1/1.3:1	+20	+15	250
APTW5-25502700-140K10-WR34D22	25.5-27.0	48	±1.5	130	1.4:1/1.4:1	+10	+15	250

MMIC Amplifiers								
Part Number	Frequency (GHz)	Gain (dB)	G.F. (dB)	N.F. (dB)	I/O VSWR	P@1dB (dBm)	Single Bias V (V)	I (mA)
AGM-058	2-4	34	±0.5	0.6	1.5:1/1.3:1	13	+4	150
AGM-003	4-8	26	±0.5	0.9	1.3:1/1.7:1	10	+5	125
AGM-001	1.5-24	15	-	2.5	1.5:1/1.4:1	10	+5	45
AGM-040	17-20	21	±1.0	-	1.1:1/1.4:1	Psat +35	+28	100
AGM-052	27-31	22	±0.5	-	1.5:1/1.7:1	Psat +35	+18	210

All AmpliTech amplifiers are MADE IN USA with:

Reverse Voltage Protection - Internal Regulation - State-of-the-Art PHEMT Technology - MIL-883, MIL-45208 Assembly Standards



**AmpliTech Group A Nasdaq Company
traded under symbol "AMPG"**



155 Plant Ave, Hauppauge, NY 11788
Phone: 631-521-7831 • Fax: 631-521-7871 • Email:
info@amplitechinc.com www.Amplitechinc.com



RF Amplifiers and Sub-Assemblies for Every Application

Delivery from Stock to 2 Weeks ARO from the catalog or built to your specifications!

- Competitive Pricing & Fast Delivery
- Military Reliability & Qualification
- Various Options: Temperature Compensation, Input Limiter Protection, Detectors/TTL & More
- Unconditionally Stable (100% tested)

ISO 9001:2000
and AS9100B
CERTIFIED

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1dB	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

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 @ P1dB	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 @ P1dB	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 @ P1dB	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

CIAO Wireless can easily modify any of its standard models to meet your "exact" requirements at the Catalog Pricing.

Visit our web site at www.ciaowireless.com for our complete product offering.

Ciao Wireless, Inc. 4000 Via Pescador, Camarillo, CA 93012
Tel (805) 389-3224 Fax (805) 389-3629 sales@ciaowireless.com





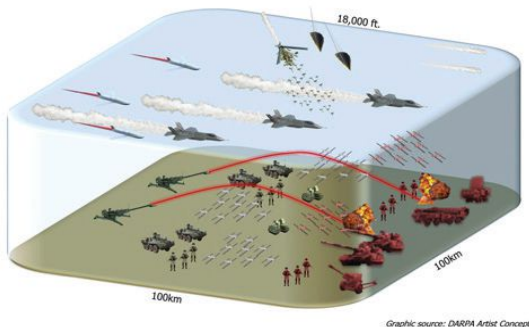
DARPA Services Demonstrate Battlefield Airspace Deconfliction Software

DARPA's Air Space Total Awareness for Rapid Tactical Execution (ASTARTE) program recently demonstrated new automated flight-path-planning software that successfully deconflicted friendly missiles, artillery fire and manned and unmanned aircraft while avoiding enemy fires in a simulated battle in contested airspace. In a demonstration held at the U.S. Army's Mission Command Battle Lab, Ft. Leavenworth, Kan., the ASTARTE software seamlessly integrated with the Army's Integrated Mission Planning and Airspace Control Tools (IMPACT) software suite.

The ASTARTE program is a joint collaboration between DARPA, the Army and the U.S. Air Force to enable efficient and effective airspace operations and de-confliction in a highly congested anti-access/area denial environment. The program's goal is to provide an accurate, real-time common operational picture of the airspace over an Army division, enabling long-range fire missions, as well as manned and unmanned aircraft operations, to occur safely in the same airspace.

ASTARTE performer Raytheon Technologies developed an automated flightpath-planning capability for fixed and rotary wing aircraft, which includes the capability to deconflict airspace use by routing through or around defined airspace coordinating measures, in both space and time. General Dynamics Mission Systems (GMDS) developed the Army's IMPACT suite, which adds a Joint All-Domain Command and Control (JADC2) class of data-enabled, over-the-horizon tools to existing airspace management systems to form a multi-domain capability supporting the Army's 2030 Multi-Domain Operations vision.

During the demonstration, GMDS and Raytheon identified the interfaces allowing the ASTARTE flight-path planner to receive flight path requests with associated constraints from IMPACT (e.g., timing, altitude range, start and end points), and returned complete deconflicted flight paths back to IMPACT on demand.

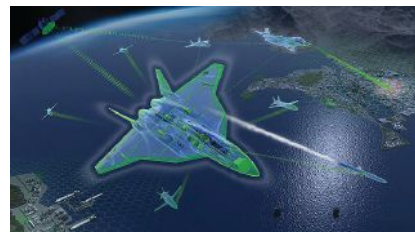


ASTARTE (Source: DARPA)

Graphic source: DARPA Artist Concept

HENSOLDT Receives Contract as Part of German-French-Spanish FCAS

Sensor solutions provider HENSOLDT is developing essential core elements of the novel sensor network in the German-French-Spanish Future Combat Air System (FCAS). As a member of the German Future Combat Mission System (FCMS) consortium, HENSOLDT has been awarded a contract worth approximately €100 million by the French procurement authority DGA for the development of demonstrators in its core competence fields of radar, reconnaissance and self-protection electronics and optronics as well as the overarching networking of sensor technology.



FCAS (Source: HENSOLDT)

In the FCAS project, the participating nations want to develop, among other things, a successor system for the Eurofighter and Rafale fighter aircraft as well as a novel system of networked sensors. By 2025, several technology demonstrators will be developed to show the possibilities of a platform-independent networked solution. This sensor network with different platforms will then be further developed in the other FCAS demonstrator phases.

The respective technology leaders of the industry from the three countries are involved: Under the overall management of INDRA (Spain), Thales for France and the FCMS consortium for Germany, consisting of HENSOLDT, Diehl Defence, ESG Elektroniksystem – und Logistik-GmbH and Rohde & Schwarz, are working together in the so-called demonstrator Phase 1b. HENSOLDT leads the FCMS consortium and therefore, in addition to its technical work packages, also takes on essential tasks in project management and in the central architecture work packages.

Lockheed Martin Awarded Initial Contract to Provide Nation's First Sea-Based Hypersonic Strike Capability

The U.S. Navy awarded Lockheed Martin a contract worth more than \$2 billion, if all options are exercised, to integrate the Conventional Prompt Strike (CPS) weapon system onto ZUMWALT-class guided missile destroyers. CPS is a hypersonic boost-glide weapon system that enables long-range missile flight at speeds greater than Mach 5, with high survivability against enemy defenses.



CPS (Source: Lockheed Martin)

Under this contract, prime contractor Lockheed Martin will provide launcher systems, weapon control, All Up Rounds (AURs), which are the integrated missile components, and

platform integration support for this naval platform. The company, along with subcontractors Northrop Grumman and General Dynamics Mission Systems, is on track to provide the CPS surface-launched, sea-based hypersonic strike capability to sailors by the mid-2020s. The contract also provides for additional AURs plus canisters for the U.S. Army's long range hypersonic weapon (LRHW) testing, training and tactical employment.

CPS shares a common AUR with the Army LRHW and can be launched from multiple platforms including surface ships, submarines and land-based mobile launchers. The combination of the CPS capability, and the stealth and mobility of the ZUMWALT-class destroyer, will provide the nation's first sea-based hypersonic strike capability.

Raytheon Awarded Contract for Missile Warning and Tracking



Raytheon Technologies received an award valued at more than \$250 million to design, develop and deliver a seven-vehicle missile tracking satellite constellation, as well as support launch and ground operations by the Space Development Agency.



SAT Constellation (Source: Raytheon Technologies)

A constellation of low earth orbit (LEO) satellites provides missile warning, missile tracking and enhanced situational awareness.

Once deployed, the LEO constellation of networked satellites will become the fifth plane of satellites providing missile warning and tracking for the Department of Defense. The program is a key element of the Proliferated Warfighter Space Architecture.

Raytheon will leverage existing designs, available commercial products and common components to reduce technical risk and speed delivery.

ELECTRONICS & DEFENSE





MRO 50 - RUGGEDIZED MINI-RUBIDIUM OSCILLATOR

A breakthrough microwave optical double resonance (MODR) low SWaP-C Miniaturized Rubidium Oscillator designed to meet the latest commercial, military and aerospace requirements where time stability and power consumption are critical.

Operating Temperature
-40° to +80°C

DC power
0.45W @5V and 0.36W @3.3V





safran-electronics-defense.com
@SafranElecDef



Reactel, Inc.

Reacting First to All Your Filter Needs.

California Dreaming



Visit us at Booth #614 while in San Diego for IMS2023 or contact us at reactel@reactel.com so Reactel's engineers can help you solve your complex filtering needs.

No matter the system problems, we will design the solution. Reactel is your answer - You have found the recognized source of filters, multiplexers and multifunction assemblies covering DC to 67 GHz. Our wide variety of topologies offer solutions to the most challenging requirements.

Reactel is your source for RF & Microwave Filters, Multiplexers and Multifunction Assemblies covering DC – 67 GHz. Trust Reactel's highly skilled engineers to quickly develop and produce the most reliable products for your filter requirements.

8031 Cessna Avenue • Gaithersburg, Maryland 20879 • (301) 519-3660 • reactel@reactel.com • reactel.com





3 MHZ TO 11 GHZ

Voltage Controlled Oscillators

The Industry's Widest Selection

- Wide selection in stock and cost-effective custom designs
- Spot frequency, narrow, medium and wideband—up to 1.5 octaves
- Better phase noise than IC oscillators, as low as -111 dBc/Hz @ 1 kHz offset
- Available in SMT, connectorized and plugin formats
- Sizes as small as 0.175 x 0.175 x 0.075"

Special Features

- Linear tuning
- Coupled auxiliary output
- Dual VCOs in shared housing
- Separate modulation port
- 5V PLL implementation





6G: Why is it Needed and What are the Challenges?

Compared to its predecessor, 6G is expected to offer significantly better communication capabilities, such as Tbps-level peak data rates, microsecond-level latency and 99.99999 percent network dependability.

Even though several important companies and nations have already begun 6G research, the telecom industry needs to address several issues before seeing the success of 6G. Difficulties include THz technology and identifying applications that will fuel 6G adoption.

6G will use a spectrum above 100 GHz and will ultimately reach THz. The advantages of employing such a high frequency are obvious: huge bandwidth may be used, allowing for Tbps peak data flow with microsecond-level latency. However, there are several limitations to employing such a high frequency spectrum.

One of the most significant challenges ahead is that the THz signal attenuates considerably in the air, restricting the transmission range and making it easily blocked by obstructions. Because the laws of physics cannot be ignored, the most crucial element for creating a device for high frequency communication is to provide enough energy to achieve a reasonable transmission range, even as part of an antenna array.

Choosing the right semiconductors to increase link range is the most critical. When it comes to frequencies above 200 GHz, a combination of CMOS for logic and III-V transistors for low noise amplifiers and power amplifiers will be the way to go. SiGe BiCMOS technology currently provides the best compromise in terms of performance, low-cost and simplicity of integration from 200 to 500 GHz. InP could be the ultimate THz technology and may be suitable in applications where cost is not the primary concern.

Despite carriers' touting the superior performance that 5G mmWave provides, the mmWave market has yet to take off despite years of 5G's commercialization. The vast majority of 5G build-outs continue to use 5G sub-6 GHz. The reasons? The one reason that most people

mention, according to IDTechEx's primary interviews, is the absence of applications that can be only enabled by mmWave and no other technologies. The same question about 6G will be asked: why is it needed?

From a consumer's perspective, having a Tbps data link and microsecond-level latency but paying a higher subscription fee will probably not be attractive if the applications on their mobile devices are similar to what they have right now.

For more details, see the IDTechEx 6G market research report, "6G Market 2023-2043: Technology, Trends, Forecasts, Players."

Soaring Demand for Global Connectivity Drives Satcom Terminal Sales

Satcom has entered a period of renewed interest with innovative technological advances, mainly driven by ballooning investment dollars in the high-growth space technology segment and the demand for global connectivity. The satcom ecosystem has two segments: ground equipment and space. ABI Research foresees sustained ground segment growth from the satcom terminals market, potentially reaching a market value of \$15.6 billion by 2030.

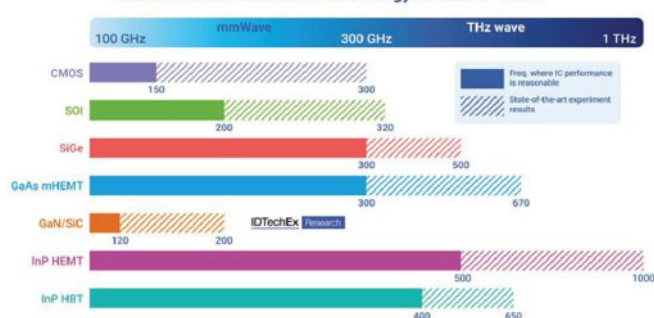
Interest has been growing in how satcom might complement or even integrate with terrestrial communications networks. Dean Tan of ABI Research explained, "The 3GPP, the satcom industry and the terrestrial wireless vendors have been studying and evaluating technology to enable non-terrestrial network (NTN) mobile applications. NTN Mobile is still very nascent, but very-small-aperture terminal (VSAT) and Broad Global Area Network (BGAN) satellite solutions are very much the mainstays of the current satcom terminals industry."

From the research findings, ABI Research has also found that the VSAT satcom solutions will have the lion's share of the satcom market revenue, at over 80 percent. VSAT systems will remain largely the satcom choice throughout the forecast period.

In different aspects of product differentiation, various models, technological innovations and the sheer number of manufacturers, VSAT satcom systems also have a substantial lead over BGAN satcom systems. The satcom terminals market will be largely represented by Gilat Satellite Networks, Cobham satcom, Intellian, Vi-sat, Hughes Network Systems, KVH and ST Engineering's iDirect. These key players will be the driving force in technological and product innovation in the satcom terminals market.

ABI Research found that the North American region, particularly the U.S., will be the dominant region in demand and revenue for satcom. ABI Research also estimates that the North American region would make up over 30 percent of the global satcom terminals market.

Overview of Semiconductor Technology Choice for THz RF



Semiconductor Technology (Source: IDTechEx)

For More
Information

Visit mwjournal.com for more commercial market news.

RF Front-End: At the Heart of the Turmoil?

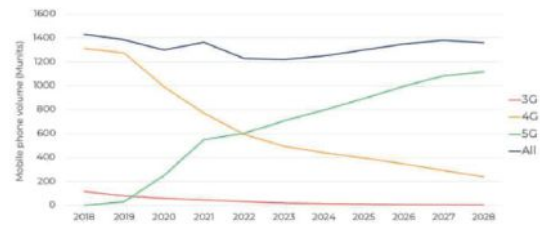
In 2022, the smartphone industry was seriously impacted following a global macro-economic downturn: a market decline with high inflation caused by geopolitical tensions such as the Russia-Ukraine war and tensions between China and Taiwan. This downturn resulted in consumer hesitancy in purchasing new phones, thus pushing OEMs to enter an inventory correction phase. In addition, the Zero-COVID policy in China further destabilized the smartphone manufacturing industry.

Yole Intelligence released its RF annual report, RF Front-End for Mobile 2023. With this report, the company aims to provide a comprehensive view of the RF front-end market from the system level down to the wafer level. It encompasses the ecosystem and technology landscape while providing insight to anticipate technology disruption.

The RF front-end market leaped forward in 2021, reaching over US\$19 billion as an effect of the post-COVID-19 recovery and 5G penetration. But the 2022 calendar year ended flat following the smartphone market decline associated with lower-than-expected 5G penetration. Consequently, the BOM growth engine has been in low gear.

2018-2028 MOBILE PHONE VOLUME FORECAST
PER AIR STANDARD (MUNITS)

Source: RF Front-End for Mobile 2023 report, Yole Intelligence, 2023



www.yolegroup.com | Yole Intelligence 2023

Mobile Phone Forecast (Source: Yole Group)

As per the moderate smartphone growth expected toward 2028, along with the limited potential for 5G penetration, Yole Intelligence forecasts a mid-single digit CAGR for the RF front-end market, which is expected to reach US\$26.9 billion by 2028. Meanwhile, the market opportunity is huge, and new 5G technical features will keep driving RF front-end technology innovations. Mid- to long-term, there are developments in the pipeline and investments are being made to prepare for the next growth wave, which will emerge from 5G advanced and the forthcoming 6G.

ADVANCED GaN on SiC AMPLIFIERS

Ultra Broadband Product Testing



USER SELECTABLE

- Output Power Management
ALC, AGC, MGC
- Input and Output Detectors
RMS, Peak
- Modulation Modes
Frequency Hopping, QAM-xx,
OFDM, Multi-carrier, Pulse,
AM, FM, CW

⊙ Broad Selection of Modules
for Communications or
Product Testing ⊙



PROFESSIONAL MANUFACTURER FOR RF/MICROWAVE CERAMIC CAPACITORS



DLC70 SERIES HIGH Q RF/MICROWAVE MLCC

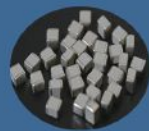
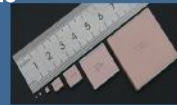
Features:

High Q/Zero TCC/Low ESR/ESL
Ultra-stable Performance/
Extended WVDC

Size : 0402,0603,0505,0805,0710,1111,2225

3838 for RF/Microwave; 6040,7575,
130130 for High RF Power

Typical Applications: Filters, RF Power
Amplifiers, Antenna Tuning, Plasma
Chambers, Medical(MRI Coils) and Transmitters

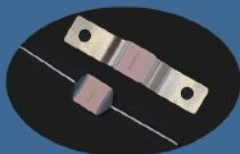


DLC75 SERIES ULTRA-LOW ESR RF/MICROWAVE MLCC

Features: Ultra-low ESR, High Working
Voltage, High Self-Resonance Frequency

Typical Applications:

Cellular Base Station
Wireless Communications
Trunked Mobile Communication System



MICRO-STRIP/LEAD MLCC

Features:

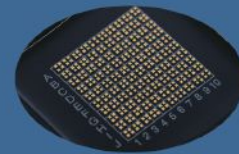
Originated from DLC70 series
Suitably soldering in various
surface mount and leaded style
Available size above 1111
Available for customized products



HIGH POWER ASSEMBLY

Features:

Capacitance and space matched well
Fully customized for high power application
Easy to solder
Highly integrated and easy to handle



SINGLE LAYER CAPACITOR

Features:

Broadband application up to 100GHz
Standard capacitance range 0.05pF
to 10,000pF
Voltage rating up to 100 WVDC
Minimum dimension size 10mil×10mil
Custom value and size are available



DALIAN DALICAP TECH. CO.,LTD.

Web: www.dalicap.com

E-mail: dalicap@dalicap.com.cn

Phone: 86-411-87632359

Fax: 86-411-87613784



Dalicap

JOIN US

We are looking for channel
partners globally.

If you are interested, please
contact us.



Around the Circuit

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

MACOM Technology Solutions Holdings Inc. announced that it has acquired **Linearizer Communications Group**, a developer of industry-leading products located in Hamilton, N.J. Linearizer was founded in 1991 by Dr. Allen Katz and specializes in non-linear microwave predistortion for use in terrestrial, avionic and space-based applications and high performance microwave photonic solutions for use in the industrial and defense markets. The Linearizer team uses proprietary design and manufacturing techniques to produce its high performance components and subsystems. Linearizer has a long history of service to its loyal customer base, which is primarily in North America.

NI announced the acquisition of **SET GmbH**, long-standing experts in aerospace and defense test system development and recent innovators in power semiconductor reliability test. Together, the companies will reduce time to market for critical, highly differentiated solutions and accelerate semiconductor-to-transportation supply chain convergence with power electronic materials such as SiC and GaN. NI first announced a strategic minority investment in SET in 2020 to help aerospace and defense companies solve soaring development costs and integration challenges. The collaboration enhanced a system-on-demand and model-based test approach delivered to shorten time to market schedules, reduce program risk, integrate labs and optimize data and assets.

Infineon Technologies AG and **GaN Systems Inc.** announced that the companies have signed a definitive agreement under which Infineon will acquire GaN Systems for US\$830 million. GaN Systems is a global technology leader in the development of GaN-based solutions for power conversion. The company is headquartered in Ottawa, Canada, and has more than 200 employees.

COLLABORATIONS

I-PEX and **Teramount Ltd** announced they are collaborating to advance Si photonics optical detachable connectivity for data centers and for other high speed datacom and telecom applications. The collaboration between I-PEX and Teramount will provide a breakthrough solution of detachable fiber to chip connectivity based on Teramount's self-aligning optics technology and I-PEX's ultra-precision plug and holder systems.

Anritsu Corp. announced a strategic partnership with **Spirent Communications** in Open RAN test solutions. This collaboration will play a key role in helping equipment vendors, carriers, system integrators, cloud ser-

vice providers and others to configure an Open RAN ecosystem by measuring wireless RAN O-RU characteristics, fronthaul conformance tests and end-to-end tests connecting O-DU, O-CU and Core.

NEW STARTS

Copper Mountain Technologies' (CMT) Cyprus location is now offering repair and annual verification services for European CMT customers. CMT opened its European location in 2022 to house its R&D department and support production at the manufacturing facility in Israel. It is now expanding to include service capabilities. The company is focused on supporting engineers using CMT VNAs and offers a more convenient repair location to its current and future customers in Europe, the Middle East and Asia. Customers can now select their preferred CMT service location when filling out an RMA request on the CMT website. This new service capability is added to support the growing number of CMT customers and partners around the globe.

ACHIEVEMENTS

Maja Systems Inc. announced that the U.S. Patent and Trademark Office has issued a new patent No. 11,511,640 B1 (the '640 patent) adding to the company's intellectual property position and coverage for its products in multi-gigabit wireless data connectivity. The '640 patent titled "Vehicle to Infrastructure Autonomous Data Backhaul" further strengthens the company's intellectual property position for multi-gigabit wireless peer to peer data connectivity products.

CesiumAstro announced it has been awarded a contract through the Department of Defense's (DoD) Space Development Agency to advance the company's multi-beam L-Band active electronically scanned array (AESA) antenna. Building upon prior efforts, CesiumAstro will continue developing the Link 16-compatible AESA ahead of the agency's migration to the Proliferated Warfighter Space Architecture global satellite network, the low earth orbit-based satellite constellation built to enable key DoD space capabilities. Work will focus on optimizing the antenna to support U.S. and allied military forces' common operating picture across the global battlespace.

PEOPLE



▲ Mike Winterling

Junkosha has reported changes to its executive team to take the business forward. Changes to the international management line-up were triggered by the announcement of the planned retirement of **Joe Rowan** from the role of president and CEO of the U.S.-based subsidiary. Rowan will remain in an advisory role, stepping aside for **Mike Winterling** to take over as COO.

HIGH PERFORMANCE VOLTAGE CONTROLLED OSCILLATORS



Up to
**18.0
GHz**



Features

- | Exceptional Phase Noise
- | Optimized Bands Up-to 3:1 Bandwidth
- | Planar, Ceramic & SAW Resonator Construction
- | REL-PRO Patented Technology
- | Small Size, Surface Mount
- | RoHS Compliant

Talk To Us About Your Custom Requirements



Phone: (973) 881-8800 | Fax: (973) 881-8361
E-mail: sales@synergymwave.com | Web: www.synergymwave.com
Mail: 201 McLean Boulevard, Paterson, NJ 07504



Ultrafast Digitizer

- Up to 10 GS/s with 12-bit resolution
- 12.8 GB/s continuous data streaming
- Over 3 GHz bandwidth
- Up to 16 GB internal memory

10 GS/s sampling
12-bit resolution
12.8 GB/s streaming



M5i.3357-x16

- One or two channels
- Programmable inputs from ± 200 mV to ± 2.5 V
- Streaming to memory, CPUs, or CUDA GPUs
- Free SDKs for C++, MATLAB, LabVIEW, VB.NET, Python, Java, Julia, and more

Capture, store and analyze the fastest GHz signals!

Contact us! 201 562 1999
sales@spectrum-instrumentation.com



SPECTRUM
INSTRUMENTATION

Perfect fit – modular designed solutions

US: Phone (201) 562 1999 | Europe / Asia: Phone +49 (4102) 695 60

www.spectrum-instrumentation.com

Around the Circuit



▲ Elif Balkas

Wolfspeed Inc. announced the promotion of **Elif Balkas** to CTO, succeeding the late **Dr. John Palmour**, a co-founder of Wolfspeed. In her role as vice president of R&D in Wolfspeed's materials organization, Balkas shaped the company's technical strategy on wide bandgap materials and drove its development execution to maintain Wolfspeed's position as a leader in SiC for power and RF device applications. She has overseen multiple significant technology milestones during her tenure at the company, including the development of 150 mm and 200 mm boule growth systems and processes, the dramatic reduction in crystal defect levels that saw higher device yields and advancements in wafer processing.



▲ Gilberto "Gil" Gonzalez

Quantic Wenzel announced that **Gilberto "Gil" Gonzalez** has joined the company as the new director of engineering. Gonzalez has held multiple engineering and program management leadership roles, previously at BAE Systems, GE Aviation, MIT Lincoln Laboratory and Raytheon. Gonzalez holds an M.S. engineering, electrical engineering from Walden University and an M.B.A. from the Jack Welch Management Institute.



▲ Geoffrey Key

MegaPhase announced that **Geoffrey Key** has joined the company as vice president of sales. Key will lead the sales team, working closely with the company's worldwide network of sales representatives and the solutions team to support and expand the company's growth. Most recently, Key occupied the role of vice president of sales and marketing for Dynawave/Winchester Electronics, and has held leadership positions in sales and marketing for Phonon (acquired by Microsemi Corporation), Micro Networks/Integrated Device Technology, C&M Corporation, Volex, Burndy Corporation and Thomas and Betts.

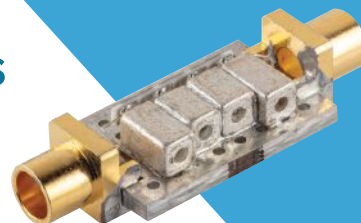


▲ Norm Hansen

Stellant Systems Inc. announced the appointment of **Norm Hansen** to director of sales. In this capacity, Hansen is responsible for managing all sales activities across the entire Stellant enterprise. This includes managing customer and sales channel relationships, achieving order intake goals and helping to identify new growth opportunities and product strategies while maintaining overall successful customer relationships. In this role, Hansen will report to Steve Shpock, COO.



When cost, size, and stability
are important, these resonators
are the best choice.



Knowles Precision Devices' coaxial ceramic resonators are made in the USA with modern, high performance ceramic dielectric materials that are valuable as compact frequency standards, filter elements, and distributed inductive or capacitive circuit elements.

The high Q obtained in the UHF, VHF, L, S, C bands and microwave frequency range makes these resonators ideal for many applications.



.....
.....



.....
.....



.....
.....



>> Learn more: rfmw.com/dielectric

Contact us today to explore a range of catalog and custom design options: sales@rfmw.com

GaN-Based Devices for Advanced RF Applications Puts Technology Building Blocks in the Spotlight

Bertrand Parvais and Hao Yu
imec, Leuven, Belgium

THE POTENTIAL OF GAN HEMTS FOR MMWAVE MOBILE COMMUNICATION

As the demand for bandwidth continues to grow and existing radio spectrum bands get congested, the telecom industry is looking for novel technologies to meet the requirements for future mobile communication. The quest for more bandwidth is inextricably linked with the use of higher radio frequencies and higher operating frequencies mean more available bandwidth. While researchers examine new III-V materials such as indium phosphide for frequencies above 100 GHz, they expect GaN-based technology to play a significant role in the lower mmWave part (i.e., below 50 GHz) of the RF spectrum. Because of this, GaN is expected to serve the next generation of 5G networks and possibly, early versions of 6G.

GAN ADVANTAGES

GaN technology owes its potential for RF/lower mmWave communication to its outstanding physical properties: it has high current density, high electron mobility and high breakdown voltage. The technology can handle switching frequencies higher than today's Si-based technology because of its high mo-

bility. Beyond speed, GaN-based technology is touted for its power handling capabilities, which make it capable of delivering high output power with good energy efficiency. These features can make GaN an attractive technology to use in the power amplifiers (PAs) that reside in the front-end modules of next-generation mobile handsets and small cells. These front-end modules send the RF signals to and from the antennas. The higher power handling capabilities of GaN compared to conventional Si- or SiGe-based technologies translate into a higher transmission range and/or into a smaller number of elements needed to drive the antennas.

REDUCING FORM FACTOR AND COST: TOWARDS A VIABLE GAN-ON-SI TECHNOLOGY PLATFORM

To be suitable as a PA in user equipment and small cells, the cost and form factor of the device can become as important as its electrical properties. As stated before, GaN helps reduce the form factor of the front-end module thanks to the inherent properties of the technology. But achieving highly-scaled form factors requires integrating the miscellaneous components of the RF front-end technology. To help

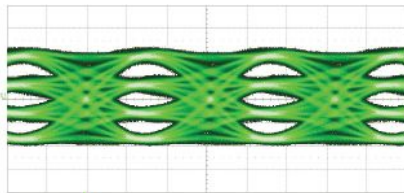
achieve this goal, imec is tuning its GaN-on-Si technology platform towards RF applications, as part of its Advanced RF program.

imec has selected GaN-on-Si rather than GaN-on-SiC for cost-saving reasons: not only are Si substrates cheaper, but the CMOS-compatible process also enables large-scale manufacturability. GaN-on-Si technology was initially developed for power electronics applications and envisioned to enable power conversion within battery chargers, computers, servers, automotive, lighting systems and photovoltaics. However, several technology innovations are required to make GaN-on-Si suitable for mobile RF applications. Parasitics within the device structures must be suppressed as much as possible to reach high frequencies. Examples of these efforts include reducing the source access resistance with methods like developing technology modules with raised source/drains and reducing gate-related parasitic capacitances. Optimizing the device for higher operating frequencies will also require a further down-scaling of the gate length. This benefits a higher f_T and f_{max} , which is a measure of the intrinsic speed of the device. Furthermore, the buffer layer must be made RF-compatible

BROADBAND AMPS AND PAM4 ENCODERS

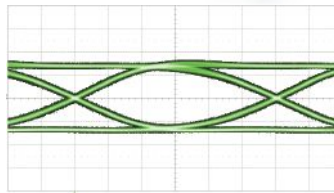
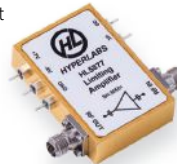
NEW: HL5887 Broadband Linear Amplifier

- Industry-leading bandwidth (42 kHz to 40 GHz)
- Optimized as a data driver for minimal eye distortion



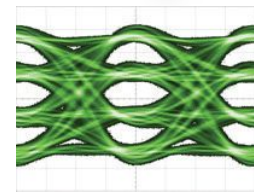
HL5877 Broadband Limiting Amplifier

- Exceptional input sensitivity with limited range of output amplitude
- Control of output amplitude and crossing point

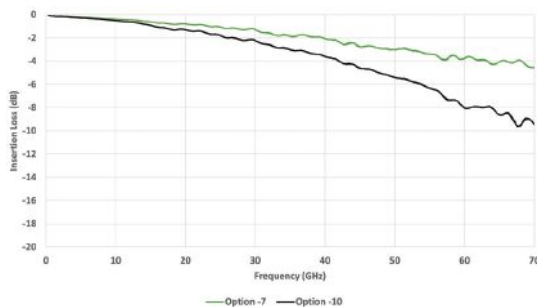


HL5567 PAM4 Encoder

- Combines two equal amplitude 50 Gb/s NRZ data streams into a single 100 Gb/s PAM4 signal



TRANSITION TIME CONVERTERS TO 7 ps/50 GHz



Available Models:

- **Designs for common standards** available off-the-shelf
- **Custom designs available** with low NRE and short lead time



HL844x BIAS TEE W/ SENSE PORT



Visit our website for baluns, pick-off tees, power dividers, risetime filters, DC blocks, amplifiers, and more!



PUT HYPERLABS IN YOUR LAB

ULTRA-BROADBAND

We offer some of the broadest band components on the market. Our engineers are constantly working on new designs and expanding our product line.

Components that are "invisible" with regards to bandwidth roll-off and jitter performance keep pulse and eye fidelity at their best. We design our products specifically to achieve these goals over the broadest band possible.

DEMOS AVAILABLE

Demos are in stock for most offerings, and we will get them in your lab quickly for a "hands on" evaluation.

CUSTOM DESIGNS

Don't see exactly what you need? Our engineers may be able to help. Many of our products can be modified or adapted to your specific needs quickly and with low minimum order quantities.

HL OREGON
13830 SW Rawhide Ct.
Beaverton, OR 97008

HL COLORADO
315 W South Boulder Rd.
Suite 206
Louisville, CO 80027

to minimize the RF substrate losses.

imec's GaN-on-Si process flow for RF starts with the metal-organic chemical vapor deposition growth of an epitaxial structure on 200 mm Si wafers. The epitaxial structure is comprised of a proprietary GaN/Al-GaN buffer structure, a GaN channel, an AlN spacer and an AlGaIn barrier. GaN HEMT devices with TiN Schottky metal gate are subsequently integrated with a low temperature three-level Cu back-end-of-line process as shown in **Figure 1**. imec researchers used this CMOS-compatible platform to fabricate GaN HEMTs, as demonstrated at the 2020 International Electron Devices Meeting (IEDM 2020). Optimizations of the gate metal stack, contact resistance and gate length scaling up to 110 nm resulted in devices with an f_{\max} of 135 GHz, which represents a step forward towards mmWave applications. Key figures of merit for PAs are the output power and the efficiency that the transistors can deliver. Competitive results are obtained on imec's GaN-on-Si platform, reaching a power-added efficiency (PAE) of 60 percent and a saturated power output (PSAT) of 2 W/mm for an 0.19 μm gate length (L_G) device at 6 GHz. These results, presented at European Microwave Week 2022, are shown in **Figure 2a**. **Figure 2b**, presented at IEDM 2022, benchmarks the performance of the imec GaN-on-Si process versus other GaN-on-Si and GaN-on-SiC processes. The imec data in red is among the best reported for GaN-on-Si devices and comparable to GaN-on-SiC devices. Using shorter gate lengths improves the measured performance at 28 GHz.

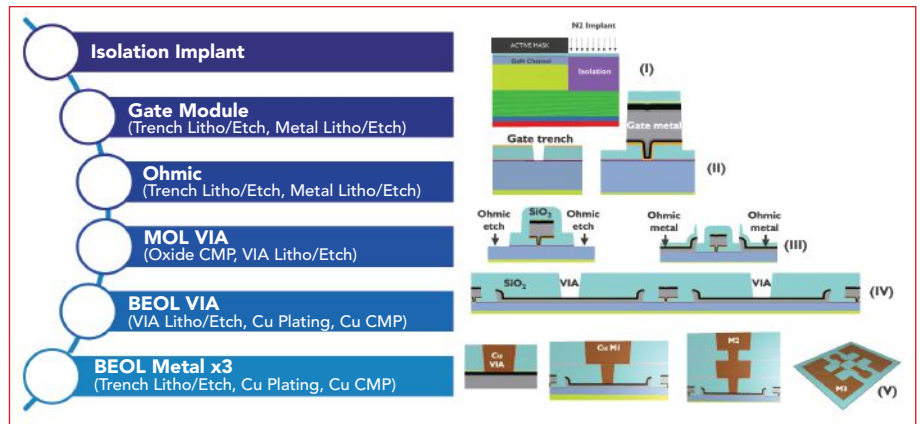


Fig. 1 Three-level Cu back-end-of-line process flow for GaN-based mmWave devices.

With these improvements, imec believes that the PAE of amplifiers designed to meet user equipment requirements and fabricated with a GaN-on-Si process achieve parity with equivalent GaN-on-SiC amplifiers for the first time.

Driven by the growth of the power electronics market in recent years, GaN-on-Si technology has become quite mature, mainly due to the development of technology that was initially intended for power electronics applications. Given the level of maturity, digging into the physics behind device operation provides an additional tool to improve the device characteristics. imec complements technology development with modeling activities that will ultimately help achieve better performance and reliability. The insights gained will not only benefit the development of GaN HEMT devices for mmWave applications, but they will also enable performance improvements in other application domains, including GaN-based power electronics.

DEVICE ISOLATION BY ION IMPLANTATION

As an example of these modeling activities, this section focuses on device isolation. This is one of the technology building blocks of the GaN-on-Si platform. When integrating GaN HEMTs in a common Si platform, the devices must be electrically isolated from each other, with as few leakage paths as possible between neighboring devices. This electrical isolation reduces power loss and improves the breakdown behavior of active devices. For GaN HEMTs, the ion implantation technique has already proven to be an attractive isolation approach over other isolation techniques, such as mesa etching, providing lower leakage and higher breakdown voltage of the isolation regions. The technique was initially developed for GaN-based power electronics applications, where it is still one of the isolation techniques actively being used today.

Ion implantation introduces several defects into the GaN hetero-

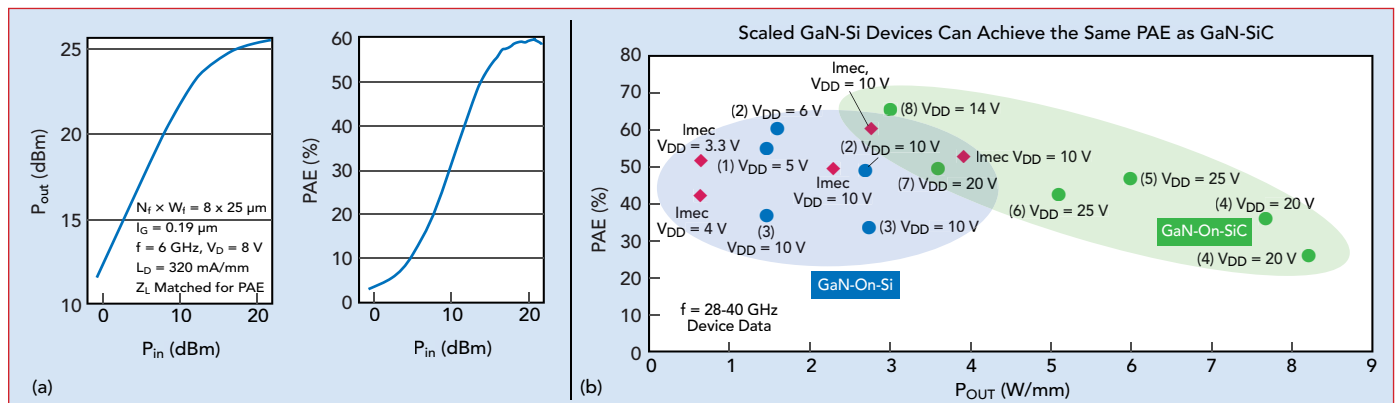


Fig. 2 (a) Large signal performance of imec's GaN-on-Si transistors. (b) GaN-on-Si benchmarking data.

ENGINEERED FOR
NEW SPACE



Ka-Band High Power Amplifier

ERZ-HPA-2550-2700-37

- Solid-State Power Amplifier
- Frequency: 25.5 to 27 GHz
- Output power: 5W
- Compact and light enclosure

Increase Your Data Transfer Rate for a Fast-Paced World

The demand for faster, more reliable satellite communication is a driving force for the engineering team at ERZIA. Our latest three-stage, solid-state, Ka-band HPA is built with GaAs and GaN technologies to provide increased reliability and efficiency in a compact, lightweight enclosure. If it's time to increase your data transfer speeds in your Ka-band payload, ERZIA has an ideal COTS solution for you.

For complete specs, visit:

erzia.com/products/hpa/770

ERZIA
WE TAKE YOU FURTHER

Wire-bondable Ceramic Components

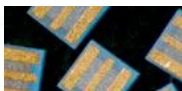
Tecdia is an industry leading manufacturer of ceramic electronic components for the RF/Aerospace & Defense market established since 1976.

Single Layer Capacitors



- 10x10 mils
- 0.1pF-10nF Capacitance Range
- Class 1 NPO/COG Dielectric Available
- Low ESR/High Q
- Epoxy & Solder Compatible
- Customizable Dimensions & Metal Finish

Thin Film Resistors



- 16x16 mils
- 10Ω-1kΩ
- 100mW Power Handling
- Wire-bondable Gold Finish
- Consistent Frequency Response
- Epoxy & Solder Compatible
- Customizable Dimensions & Metal Finish

Tecdia Inc.

Phone : 1-408-748-0100

Email : sales@tecdea.com

Location : 2255 S. Bascom Ave., Ste. 120, Campbell, CA 95008, U.S.A.



Technical Feature

structure that act as trapping centers for the charge carriers. In terms of physics, these defects pin the Fermi level away from the conduction or valence band of GaN. Implanting ions, such as nitride (N) ions, in the region surrounding the devices will reduce the number of conductive free carriers, creating an electrically insulating region. In experiments, researchers have also observed that the ion implantation-induced damages disappear after annealing at high temperatures, typically above 600°C, thereby compromising isolation quality. Featuring a low post-epitaxy thermal budget, imec's GaN-on-Si manufacturing flow guarantees high-quality isolation of HEMT devices. imec has already demonstrated a GaN HEMT ion implantation isolation technique that contributes to the highest reported sheet resistance, with values in the range of 10^{13} to 10^{15} Ω/sq. This is an essential metric for quantifying isolation. **Figure 3a** and **Figure 3b** illustrates benchmarks of the sheet resistance (R_{sh}) of AlGaIn/(AlN)/GaN heterostructures subjected to ion implantation isolation with varying activation energy magnitudes and peak heating temperatures. The benchmark in Figure 3a suggests a common physical mechanism behind isolation, while the benchmark in Figure 3b indicates the dominant impact of processing temperature on isolation quality.

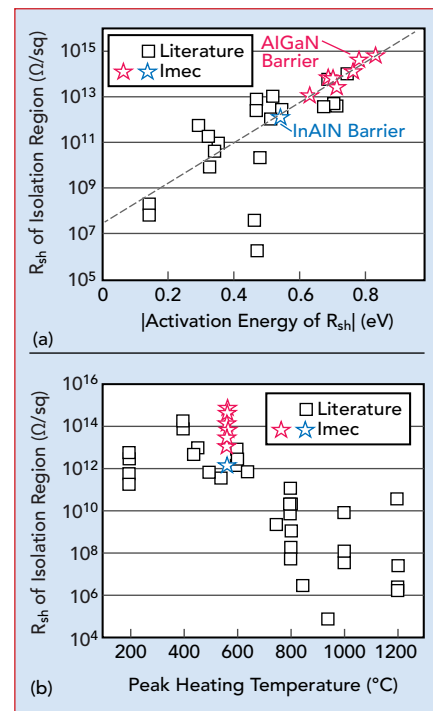
THE MECHANISM BEHIND ION IMPLANTATION ISOLATION: A FUNDAMENTAL INSIGHT

Why this technique works so well and precisely where the remaining current leakage path is formed has remained a mystery. A fundamental understanding and modeling of the leakage mechanism in ion-implanted regions is needed. This could help improve the process conditions such as thermal budget, implantation dose and energy for various applications, including mmWave communication.

There is a reason why it is so difficult to understand the exact mechanism behind the insulation. The ion-implanted region is full of defects of various natures. There are point defects, such as vacancies or interstitial atoms, defect complexes, foreign

ion impurities and lattice disorder to name a few. In addition, polarization charges reside at the interface between AlGaIn and GaN. This complex cocktail of defects and charges makes it highly challenging to simulate the behavior of the charges within the isolated heterostructure and to locate the leakage path.

By combining experimental and modeling work, imec researchers have unveiled the leakage mechanism in isolated GaN-based heterostructures for the first time. The details of this work have recently been published in the *Journal of Applied Physics*.⁹ By setting up dedicated experiments with varying AlGaIn and AlN thicknesses, researchers extracted and analyzed the sheet resistances of the isolated regions and the corresponding activation energies. The conclusion from these experiments was that the dominant leakage occurs via an ohmic path of electrons at the GaN surface. Revert to the terms of physics, this translates into a downward bending of the GaN conduction band near the GaN surface. These insights laid the foundation for more detailed modeling of the isolated heterostructure and for reconstruct-



▲ Fig. 3 (a) Benchmark of sheet resistance versus activation energy magnitude. (b) Benchmark of sheet resistance versus peak heating temperature.

MI-WAVE

Millimeter Wave Products Inc.

www.miww.com

Commercial
Telecommunications
Defense
Space

**AMPLIFIERS
OSCILLATORS
AND MORE**



MILLIMETER WAVE PRODUCTS AND SOLUTIONS

FROM CUSTOM COMPONENTS TO FULL SUBSYSTEM BUILDOUTS

All components and assemblies are manufactured and tested in our US based facility

Our capabilities range from standard off-the-shelf components to custom designed assemblies and subsystems, Prototype to large volume manufacturing from 7 to 325 GHz. We work with a wide variety of customers from educational, commercial and government related industries. All components and assemblies are produced, inspected and tested using the latest state-of-the-art technology to ensure quality and high reliability.



955 series

High Power Amplifiers Fixed Phase-Locked Oscillators

Frequency- Gains -Pout

27-31 GHz, 31 dB, 20 Watts
26.5-40 GHz, 40 dB, 4.0 Watts
49.5-50 GHz, 40 dB, 25 Watts
49.5-50.5 GHz, 40 dB, 50 Watts
65-70 GHz, 35 dB, 3.0 Watts
71-76 GHz, 25 dB, 5.0 Watts
92-96 GHz, 30 dB, 4.5 Watts



957 Series

Frequency- Power Out

18.0-26.5 GHz, Pout= 30 bBM
26.5-40.0 GHz, Pout= 30 bBM
33.0-50.0 GHz, Pout= 30 bBM
40.0-60.0 GHz, Pout= 30 bBM
50.0-70.0 GHz, Pout= 30 bBM
60.0-90.0 GHz, Pout= 30 bBM
75.0-110.0 GHz, Pout= 30 bBM



**Higher Performance
at Lower Cost
through Innovative
Engineering**



Agile
Microwave Technology Inc



BROADBAND POWER AMPLIFIERS

- ▶ 2 – 18 GHz 8W, 10W and 15W
- ▶ 0.5 – 18 GHz 1W, 2W and 4W
- ▶ Compact Size
- ▶ Competitive Price & Fast Delivery



LNA with 5W PROTECTION

- ▶ Broadband Performance to 40 GHz
- ▶ Low Noise Figure
- ▶ Medium Power up to 1W
- ▶ 5G Amps from 25 to 43 GHz

WEBSITE with:

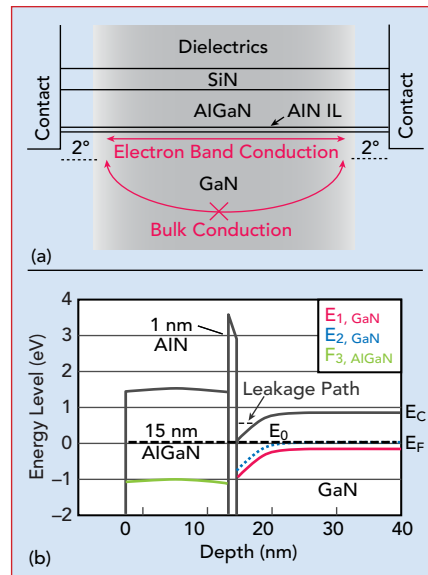
- IN STOCK Amplifiers
- Parametric Search Capabilities

984-228-8001

www.agilemwt.com

ISO 9001:2015 CERTIFIED

Technical Feature



▲ Fig. 4 (a) Diagram illustrating surface and bulk leakage paths in transmission line model structures. (b) Energy band diagram of the AlGaIn/AlN/GaN heterostructure showing band bending at the GaN surface.

ing its energy band diagrams. The theory helped extract the net defect densities in these isolated implanted regions, which amounted to $\sim 2 \times 10^{19} \text{cm}^{-3}$ and $\sim 2 \times 10^{18} \text{cm}^{-3}$ for GaN and AlGaIn, respectively for these experiments. The majority of those defects are found as point defects. The point defects were created by ion implantation techniques and preserved from recombination with imec's low thermal budget HEMT fabrication. The high densities of point defects are essential to limit the GaN surface energy band bending and thus limit the leakage.

Figure 4a and **Figure 4b** illustrate the leakage mechanism in GaN heterostructures. Figure 4a shows the surface path leakage path versus bulk leakage path in transmission line model structures. Figure 4b illustrates the energy band diagram of the AlGaIn/AlN/GaN heterostructure showing band bending at the GaN surface.

CONCLUSION

For the first time, imec researchers have unveiled the exact mechanism behind ion implantation as a technique for electrically isolating GaN HEMT devices. These insights help improve the process conditions to obtain good isolation quality when targeting RF/mmWave

communication. The findings can be extended to power electronics applications as well. Moreover, the study led to a novel method to estimate the net defect density in isolated GaN-based heterostructures. These activities fit into the broader framework of GaN device optimization for RF applications through both technology and modeling. The efforts and the results illustrate how uncovering the physics secrets behind the technology building blocks can help take these GaN-based devices to the next level of maturity. ■

References

1. H.W. Then, M. Radosavljevic, N. Desai, et al., "Advances in Research on 300mm Gallium Nitride-on-Si (111) NMOS Transistor and Silicon CMOS Integration[C]," *IEEE International Electron Devices Meeting (IEDM)*, 2020, 27.3. 1-27.3. 4, DOI: 10.1109/IEDM13553.2020.9371977.
2. H.W. Then, M. Radosavljevic, P. Koirala, et al., "Advanced Scaling of Enhancement Mode High-K Gallium Nitride-on-300mm-Si (111) Transistor and 3D Layer Transfer GaN-silicon Finfet CMOS Integration[C]," *IEEE International Electron Devices Meeting (IEDM)*, 2021, 11.1. 1-11.1. 4, DOI: 10.1109/IEDM19574.2021.9720710.
3. W. Wang, X. Yu, J. Zhou, et al., "Improvement of Power Performance of GaN HEMT by using Quaternary InAlGaIn barrier[J]," *IEEE Journal of the Electron Devices Society*, 2018, 6: 360-364, DOI: 10.1109/JEDS.2018.2807185.
4. Y.C. Lin, S. H. Chen, P. H. Lee, et al., "Gallium Nitride (GaN) High-Electron-Mobility Transistors with Thick Copper Metallization Featuring a Power Density of 8.2 W/mm for Ka-Band Applications[J]," *Micromachines*, 2020, 11(2): 222, DOI: 10.3390/mi11020222.
5. M. Mi, X. H. Ma, L. Yang, et al., "Millimeter-wave Power AlGaIn/GaN HEMT using Surface Plasma Treatment of Access Region[J]," *IEEE Transactions on Electron Devices*, 2017, 64(12): 4875-4881, DOI: 10.1109/TED.2017.2761766.
6. Y. Zhang, K. Wei, S. Huang, et al., "High-temperature-recessed Millimeter-wave AlGaIn/GaN HEMTs with 42.8% Power-added-efficiency at 35 GHz[J]," *IEEE Electron Device Letters*, 2018, 39(5): 727-730, DOI: 10.1109/LED.2018.2822259.
7. <https://hal.archives-ouvertes.fr/hal-0235688>.
8. J. Moon, J. Wong, B. Grabar, et al., "Novel High-speed Linear GaN Technology with High Efficiency[C]," *IEEE MTT-S International Microwave Symposium (IMS)*, 2019, 1130-1132, DOI: 10.1109/MWSYM.2019.8700832.
9. Hao Yu, et al., "Leakage Mechanism in Ion Implantation Isolated AlGaIn/GaN Heterostructures," *Journal of Applied Physics* 131, 035701, 2022, Web: <https://aip.scitation.org/doi/abs/10.1063/5.0076243>.

YOUR CUSTOMER CAN'T WAIT.

WHY SHOULD YOU?

**3H DELIVERS RF/MICROWAVE FILTERS
AND TECH SUPPORT FASTER.**



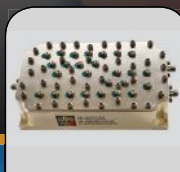
Miniature SMT,
Cavity Filters,
available from
5.0 to 25 GHz



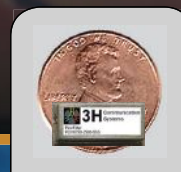
Nano, SMT Filters,
available from
40 MHz to 6.0 GHz,
in LC and Ceramic
Topologies



Pico, SMT
Filters, available
from 5.0 GHz to
27 GHz



Cavity Filter
10 MHz to 50 GHz.
Bandwidths:
0.2 to 100%.
Low or high PIM



Miniature
Diplexers,
available from
40 MHz to
27 GHz

The 3H quick-response team is ready to design and deliver DC to 50 GHz custom filter and diplexer solutions when you need them. Leadless surface mount options are available.

- Custom designed and manufactured to your specific needs
- Smallest possible package designs without performance loss
- Delivered faster — compare delivery times first!
- Better — in fact, the best customer service and engineering support!
- High- and low-power applications available in the smallest packages

AS9100 and
ISO9001:2015
Certified

RF SOI Enables 5G mMIMO Active Antenna Systems

Payman Shanjani and Vikas Choudhary
pSemi Corporation, San Diego, Calif.

The superior performance of active/advanced antenna systems (AAS) compared to traditional passive antenna systems (PAS) is driving a transition towards AAS for base stations used in telecommunications applications. These AAS are composed of several to even hundreds of antenna elements that, depending on the design, require distinct RF signal chains to the antenna elements. This approach allows for MIMO and beamforming capability, but it also dramatically increases the antenna system complexity, though generally at lower RF power per signal chain. This changes the telecommunications RF front-end (RFFE) dynamic from a small number of very high-powered signal chain components to a multitude of lower-power components with different design criteria and considerations. The latest generation of RF silicon-on-insulator (SOI) component technology is well-suited to fill this new niche for telecommunications signal chain components for both sub-6 GHz and massive MIMO (mMIMO) transceivers.

TRANSITION TOWARD AAS

Traditional cellular mobile base stations are based on a homogeneous cellular design with large base stations spaced sparsely to cover targeted regions. Covering these distances has traditionally required base stations to be located on large towers or the tops of tall buildings in more cluttered urban environments. Generally, the radio unit (RU) is in a

location that is readily accessible to technicians with the antenna placed on top of the tower or edge of the building using a remote radio head (RRH) system. The RU routes antenna signals along lossy RF coaxial cables in a PAS.

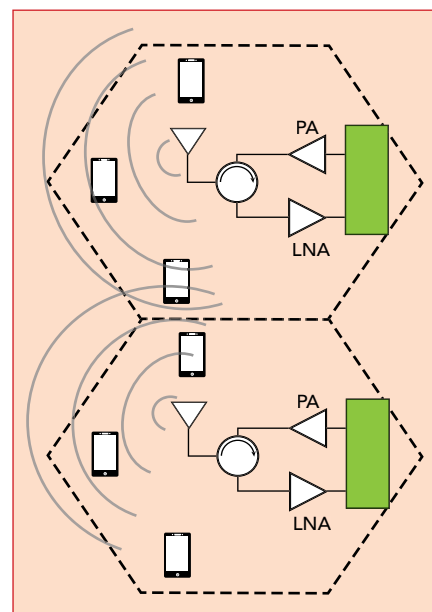
This cellular model requires omnidirectional or directional antennas that radiate over a wide coverage area to serve as many users as possible. The amount of energy received by the user equipment (UE) is low when compared to the total radiated energy, resulting in low radiated energy efficiency. With only a single large transmitting antenna, the same signal must be sent to the entire coverage area. This scheme supports a limited number of simultaneous users from a given base station and is shown in the block diagram of **Figure 1**.

This approach successfully served legacy devices and traditional use cases, but the number of mobile devices is growing. Growing numbers of devices and requirements for enhanced cellular performance are all factors driving the development of base stations using mMIMO antennas. These base stations are capable of supporting a significant number of UEs, but they necessitate a shift in architecture. As a result, there are significant ongoing development efforts aimed at MIMO and beamforming technologies to realize AAS.

The RF unit in an mMIMO AAS is located close to or integrated with the antenna. This makes the RF signal routing between the RU and an-

tennas much shorter. The mMIMO arrays route transmit and receive signals to a large number of radiating elements. These antennas have at least one RFFE per group of antenna elements and may have one RFFE per antenna element. This architecture supports mMIMO access and beamforming, resulting in an antenna system with a controllable beam pattern that is compatible with spatial multiplexing. Spatial multiplexing allows for multiple simultaneous data streams between the base station and the UE to maximize capacity and coverage. The front-end of an mMIMO AAS is shown conceptually in **Figure 2**.

These mMIMO AAS are much more compact than traditional base



▲ Fig. 1 Traditional microcell base station architecture.

EXODUS

Above the Rest

...providing
industry firsts
with our frequency
& power capabilities



AMP4066A-1LC, 26.5-40GHz, 100W

Exodus provides "Industry Firsts"
covering these frequency ranges
in all SSPA:

1.0-18.0GHz, 100W, 200W, 300W, 500W...

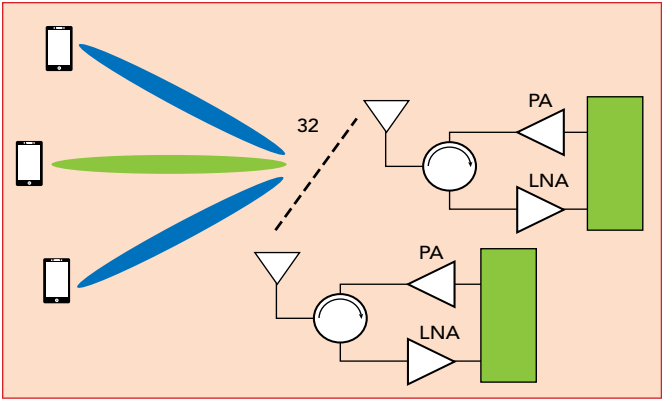
1.0-40.0GHz, as well and for the

18.0-40.0GHz range 40W, 100W, 200W

**NO OTHER COMPANY
CAN DO THIS ANYWHERE!!!**



3674 E. Sunset Road, Suite 100, Las Vegas, Nevada 89120
702-534-6564 • www.exoduscomm.com • sales@exoduscomm.com



▲ Fig. 2 Front-end of 32-element mMIMO AAS base station.

Macro	mMIMO	Small/Micro
<ul style="list-style-type: none">• Area Coverage• Targeted Sectorizing• Rural Deployment• 4T4R-8T8R• TDD Focus• Existing Sites	<ul style="list-style-type: none">• User Capacity• Urban, Semi-Urban• 32T32R (64T64R)• TDD Focus• New Sites	<ul style="list-style-type: none">• User Experience• Dense Urban• 8T8R-16T16R• TDD Focus• Local New Sites

▲ Fig. 3 Base station differentiators.

stations, with a multitude of lower-power RF signal lines replacing a single large and less efficient signal path. The MIMO capability enhances radiated efficiency because beamforming architectures and mMIMO techniques enable more directional antenna patterns, concentrating the radiated energy from the base station toward the UE. **Figure 3** lists some of the features, advantages and use cases for different base station classifications.

Depending on the use case,

MIMO and beamforming AAS can enhance the downlink and uplink signal strength and cell throughput by allocating multiple beams to one or more users. The highly directional beamforming antennas reduce transmitted and received interference. This can dramatically improve network performance within a cell and with adjacent cells, especially in interference-limited cell deployments. **Figure 4** compares the features and performance of traditional passive and mMIMO base station antennas.

	Traditional	Massive MIMO
Number of Antennas	1-4	> 8
Throughput	✗	✓
Interference	✗	✓
Multi-User Capability	✗	✓
Sensitivity	✗	✓
Antenna Gain	✗	✓
Energy Efficiency	✗	✓
Scalability	✗	✓
Link Stability	✗	✓
Expense	✓	✗
Complexity	✓	✗
Antenna Coupling	✓	✗
Baseband Processing	✓	✗
Total Power Consumption	✓	✗
Area and Weight	✓	✗

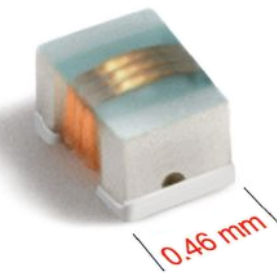
▲ Fig. 4 Comparison of traditional and mMIMO antennas. Source: Yole Developpement, "5G's Impact on RF Front-End for Telecom Infrastructure 2021."

Despite the performance benefits of AAS, there are trade-offs. The mMIMO AAS are much more complex with more internal components and routing considerations, which can make them more expensive. The enhanced performance requires more baseband and antenna processing capabilities, which can make an AAS architecture larger and heavier than traditional PAS architectures that cover the same frequencies.

Historically, wireless base stations have relied on RF transmit chains

0201CT Series

Low Profile, High Q Chip Inductors



- Measure just 0.58 x 0.46 mm and only 0.35 mm tall
- Exceptionally high Q and lower DCR than thin-film types
- 14 inductance values from 0.6 to 22 nH
- AEC-Q200 Grade 1 with a max part temperature of 140°C
- Ideal for high-frequency applications such as cell phones, wearable devices, and LTE/5G IoT networks

Coilcraft

Free Samples @ coilcraft.com

RF-LAMBDA

THE LEADER OF RF BROADBAND SOLUTIONS

EUROPE

DEUTSCHLAND



RF SWITCHES

MM / MICROWAVE DC-90GHz



160 CHANNELS
mm/Microwave

0.05-20GHz

Filter Bank Switch Matrix

For Phase Array Radar Application Satellite communication.

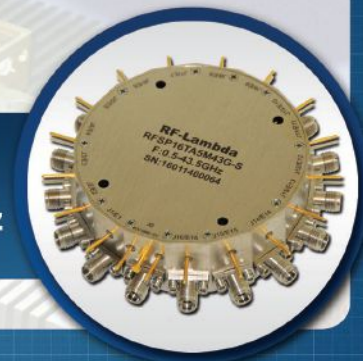


PN: RFSP32TA5M43G

SP32T SWITCH 0.5-43.5GHz

PN: RFSP16TA5M43G

SP16T SWITCH 0.5-43.5GHz

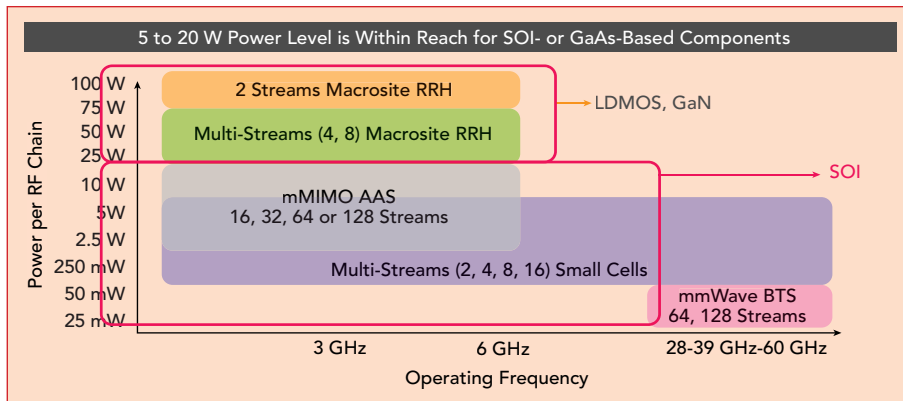


www.rflambda.com
sales@rflambda.com

1-888-976-8880
1-972-767-5998

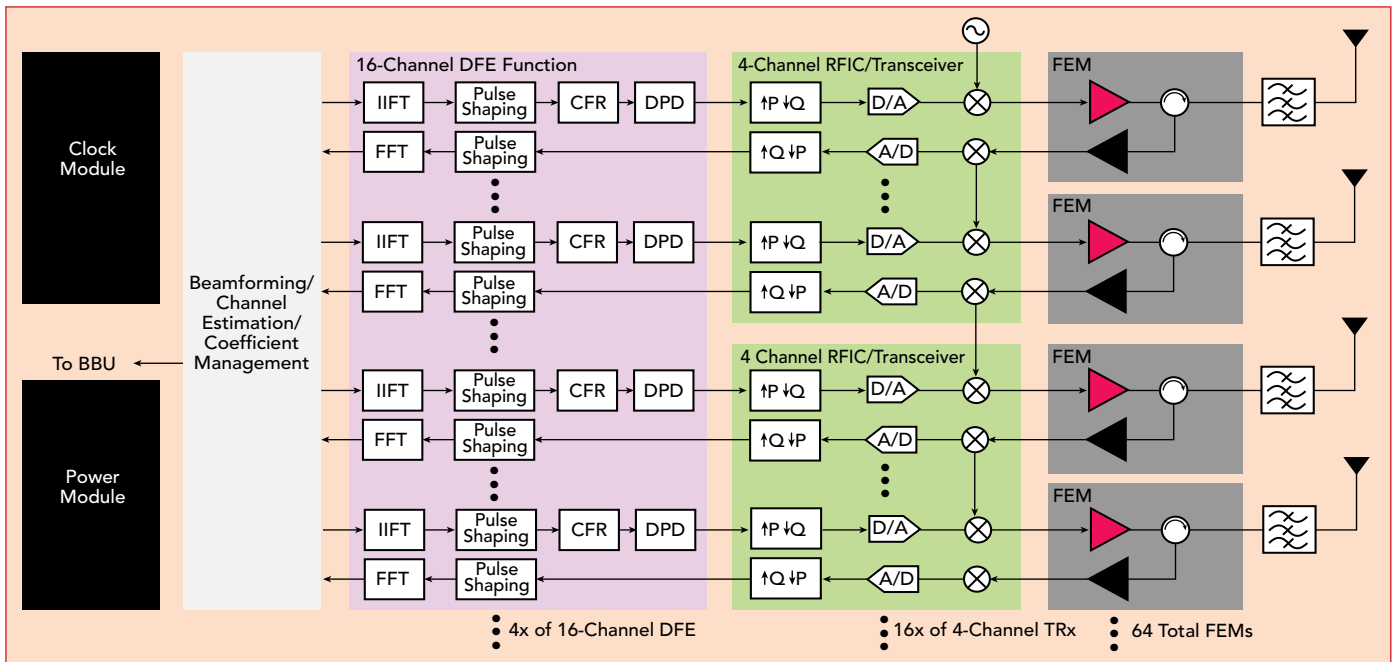
San Diego, CA, US
Plano, TX, US

Ottawa, ONT, Canada
Frankfurt, Germany



▲ Fig. 5 RF power per chain versus operating frequency.

with output powers typically above 20 W. Power amplifiers (PAs) were fabricated with LDMOS, GaAs and more recently, GaN technologies. As higher-order AAS deploys, RF power levels per signal chain decrease and this opens opportunities for other semiconductor technologies. **Figure 5** shows RF power versus operating frequency for several base station configurations. The move toward mMIMO AAS is shifting the RF power market share away from LDMOS and GaN to lower-power technologies like SOI and



▲ Fig. 6 64-channel MIMO RRU architecture.

The Trusted Source for VCOs, PLLs & Signal Sources

NEW! 9GHz Phase Locked Oscillator

The FSG9000LX is a frequency source with phase noise of $-110\text{dBc/Hz}@10\text{KHz}$ and $+15\text{dBm}$ output power.

The FSG series of DRO based phase locked oscillators are available in frequencies from 8GHz -16GHz.



Find a wide range of frequency source products, in stock, and ready to ship to meet your requirements.



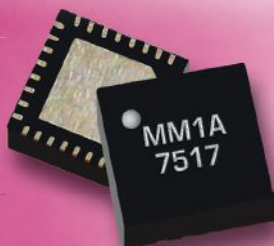
Exclusively available at STORE.ZCOMM.COM

MASTER OF MIXERS

SIMPLIFYING THE AMPLIFIER
MIXER INTERFACE

A Leading-Edge Lineup of Integrated Drive Mixers from Marki Microwave

- ✓ Eliminating the need for a separate amplifier and mixer interface
- ✓ Minimizing design costs without sacrificing performance across the operating bandwidth



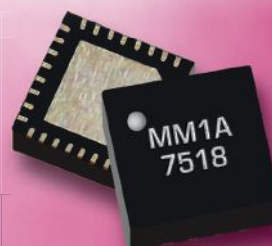
MM1A-0222HPSM

- +3 dBm minimum LO drive
- Supports 2-22 GHz RF/LO response
- 7.5 dB conversion loss
- 5.0 x 5.0 mm QFN



MT3A-0113HCSM

- +5 dBm minimum LO drive
- Supports 1.5-13 GHz RF/LO response
- 9.5 dB conversion loss
- 6.0 x 6.0 mm QFN



MM1A-0622HPSM

- +3 dBm minimum LO drive
- Supports 6-22 GHz RF/LO response
- 7.5 dB conversion loss
- 5.0 x 5.0 mm QFN



MM1A-1040HPSM

- +3 dBm minimum LO drive
- Supports 10-40 GHz RF/LO response
- 8 dB conversion loss
- 3.0 x 4.6 mm QFN



MM1A-1855HPSM

- +4 dBm minimum LO drive
- Supports 18-55 GHz RF/LO response
- 9 dB conversion loss
- 3.0 x 4.6 mm QFN



MM1A-0832HPSM

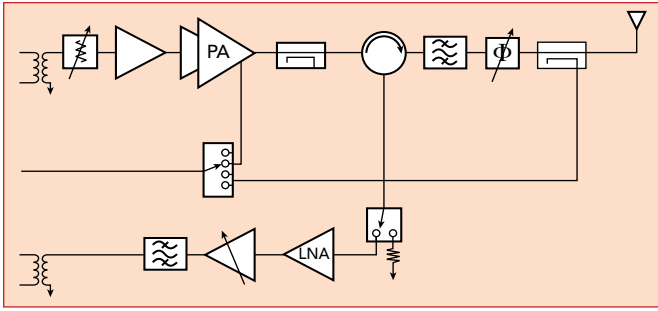
- -6 dBm minimum LO drive
- Supports 8-32 GHz RF/LO response
- 9 dB conversion loss
- 3.0 x 4.6 mm QFN

The Trusted Leader When Performance Matters

Contact: sales@markimicrowave.com

www.markimicrowave.com





▲ Fig. 7 Front-end module architecture.

GaAs. These opportunities arise as the industry appears to be converging on 32T32R and 64T64R as the wireless infrastructure architecture as shown in **Figure 6**. **Figure 7** shows more detail on the front-end module (FEM) and we see the need for switches, amplifiers, attenuators and phase shifters.

AAS HERALD SOI OPPORTUNITIES

As wireless infrastructure architectures move toward mMIMO in AAS, RF designers face challenges designing, developing and fabricating RF components and antenna systems. mMIMO AAS contain more components and they are more complex to meet increasing performance demands, but subscriber revenue growth has been sluggish. Operators are struggling to maximize their return on investment and this places substantial price pressure on system and component OEMs.

There are other ramifications. The RF power per transceiver is lower, but there are many more transceivers, which require more digital baseband processing, and this in-

creases power consumption, footprint and weight. This has direct implications for operating expense and size, pressuring RF component manufacturers to develop more efficient and more highly integrated solutions.

These factors are making SOI technology a more compelling solution for wireless infrastructure applications.

RF SOI PRIMER & ADVANTAGES

SOI technology involves fabricating silicon semiconductor devices in a layered silicon insulator-silicon-substrate. This approach improves performance by reducing parasitic capacitance within the device and to the substrate. SOI technology enjoys higher isolation, linearity, transit frequency and lower loss passive devices compared to silicon. SOI technology uses a process similar to bulk CMOS, benefiting from larger wafer sizes and well-established fabrication verticals. Despite using a silicon process, SOI transistors are not susceptible to latch-up like silicon transistors.

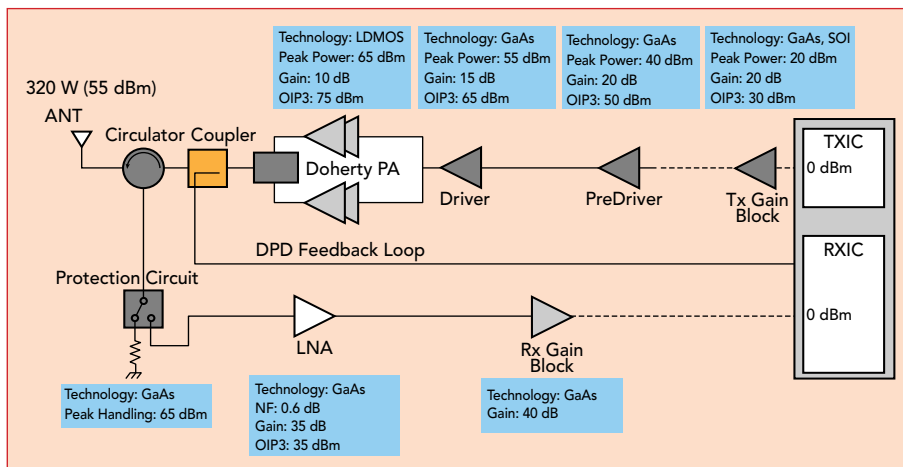
Stacking also increases the power handling capability of SOI technology. Transistor stacking increases the maximum voltage a process can handle by “floating” a series of transistors, each with a limited maximum voltage handling capability. Ideally, the maximum voltage of a stack of transistors would be the

maximum voltage of each transistor times the number of stacked transistors, allowing virtually any maximum voltage. However, the parasitic capacitance to the substrate (C_{sub}) with stacked transistors degrades the overall power handling of the stack. The higher the C_{sub} , relative to the gate-drain capacitance (C_{gd}) and the gate-source capacitance (C_{gs}), the more the stacking performance degrades. Fortunately, the very low C_{sub} of SOI technology enables very efficient stacking compared to other technologies.

SOI OPPORTUNITIES IN SUB-6 GHZ 5G BASE STATIONS

Figure 8 shows the typical performance requirements of an RRH base station in a sub-6 GHz AAS base station. The lineup highlights the typical semiconductor technology for each function. Assuming a typical receiver IC input and transmitter IC output power of 0 dBm and average radiated output power at the antenna of 320 W, or 55 dBm, limits the range of preferred technologies. LDMOS devices in a Doherty amplifier topology exhibiting a peak-to-average power ratio of 10 dB are the preferred final-stage solution for the amplifier. The peak output power of the PA will be at least 65 dBm and the gain of this stage is likely to be relatively low to support the high power level. Multiple gain stages are used to produce the required output power since each stage will have limited gain. Given the cascade requirements, the transmit (Tx) gain block is the only candidate for SOI technology. In this analysis, GaAs amplifiers support the driver stages to the output PA. A coupler at the PA output provides feedback for the digital predistortion (DPD) circuitry that enhances transmitter linearity and efficiency. This topology has a circulator at the antenna port to route the Tx and receive (Rx) signals and a receiver protection circuit, typically a high-power, non-SOI PIN diode, at the receiver low-noise amplifier (LNA) input. The Rx signal chain uses GaAs LNAs and gain blocks for the noise figure (NF) performance of that technology.

While the RRH block diagram did not have many opportunities for



▲ Fig. 8 RRH RF lineup.

Solid-State Amplifier Selection Tips for EMC Testing

Investigate the following parameters when selecting a solid-state amplifier for EMC testing:

Class of Operation

Class A solid state amplifiers are the preferred technology for EMC RI and CI testing. They are favored for repeatability of test results compared to Class AB and other types. Verify that the Class A amplifier can tolerate load mismatches and simultaneously remain operational, without amplifier damage, foldback or shutdown.

Rated Output Power

Compare actual production power curve test results, and avoid assuming rated power based on model data sheet specifications.

Linearity & Harmonic Distortion

For repeatability of test results, seek amplifiers with good linearity and low harmonic distortion. Linearity should be less than ± 1 dB (subject to your application) and harmonics are preferred below 18 dBc.

Modulation (AM, FM, PM) Performance

Modulation of CW signal is required by RI and CI test standards. Confirm that an amplifier can reproduce modulation satisfactorily to your unique application requirements.

To know more, talk to an AR applications engineer at [800.933.8181](tel:800.933.8181). AR offers over 100 amplifier models ranging from 10 kHz – 50 GHz with power levels of 1 W – 100 kW to meet your unique requirements. And as with all amplifiers from AR, these are Built to Last

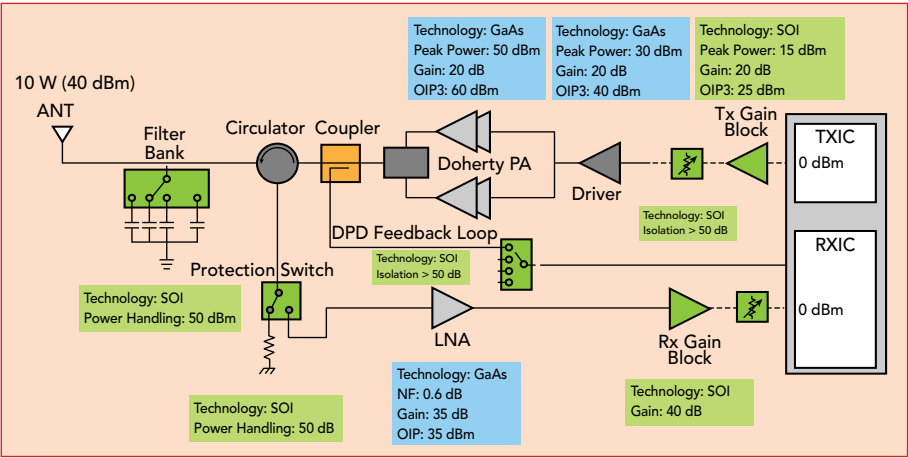
Also visit us at www.arworld.us.



SOI technology, the mMIMO AAS lineup shown in **Figure 9** does. The radiated power from each antenna

in this example is 10 W, but the total radiated power remains the same as in the earlier example. With peak PA

output power at 50 dBm, the output stage can be GaN or GaAs technology with higher gain. An SOI digital step attenuator (DSA) may be used after an SOI Tx gain block for beam adjustment. Multiple transceivers means multiple PA output couplers for DPD feedback and these couplers can feed an array of SOI SP4T switches. With lower power in each transceiver, the Rx signal chain protection circuit can be realized with SOI. A GaAs LNA is still desirable for low NF performance, but SOI can be used for the level-controlling Rx gain block and DSA at the receiver input. SOI switched-filter banks may be used at the transceiver input to enhance selectivity and output performance. SOI exhibits high power handling, high isolation and excellent linearity performance, making it



▲ Fig. 9 32T32R AAS base station RF lineup. Source: “Massive MIMO, mmWave and mmWave-Massive MIMO Communications: Performance Assessment with Beamforming Techniques” Tewelgn Kebede Engda, et al.

TABLE 1: ADVANTAGES OF BEAMFORMING TECHNIQUES			
Features	Beamforming Types		
	Analog Beamforming	Digital Precoding	Hybrid Precoding
Number of Streams	Single stream	Multi-stream	Multi-stream
Number of Users	Single user	Multi-user	Multi-user
Signal Control Capability	Phase control only	Phase and amplitude control	Phase and amplitude control
Degree of Freedom	Least	Highest	Intermediate
Implementation	Phase shifters	ADC/DAC, mixer	Phase shifter, ADC/DAC and mixer
Hardware	Least	Highest	Intermediate
Energy Consumption	Least	Highest	Intermediate
Cost	Least	Highest	Intermediate
Complexity	Least	Highest	Intermediate
Performance	Least	Optimal	Near optimal





PRONTO

PLETRONICS NEW LINE OF CERAMIC PACKAGED CONFIGURABLE OSCILLATORS. THE PRONTO SERIES ARE FEATURE RICH DEVICES SUITABLE FOR A WIDE RANGE OF APPLICATIONS.

FEATURES INCLUDE:

- < 1 week DELIVERY
- 40° C ~85° C
- LVC MOS: 1-200MHZ ; DIFFERENTIAL: 10-1500MHZ

CUBIC™

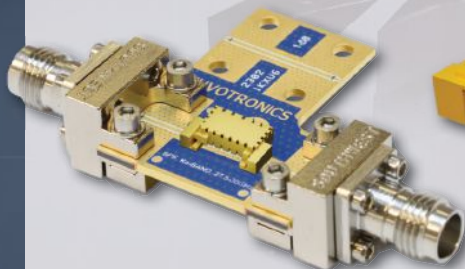


NUVOTRONICS

Superior Wideband Performance Products

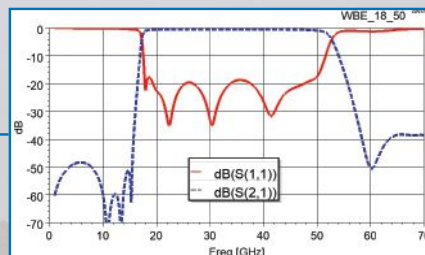
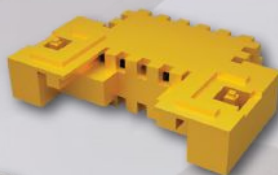
PSF29B22EVB

18-40 GHz Bandpass Filter Eval Board



PSF34B32S

18-50 GHz Bandpass Filter



PolyStrata® Products deliver performance and precision to millimeter-wave and wideband systems in a surface mount configuration

PolyStrata® Couplers

Surface Mount form factor

» Ease of integration and assembly

Near Ideal Coupling

» 3 dB coupling across band

High Isolation

» Over 20 dB isolation between channels

PSC50D07S

18-50 GHz Directional Coupler



PSC50H08S

18-50 GHz Coupler



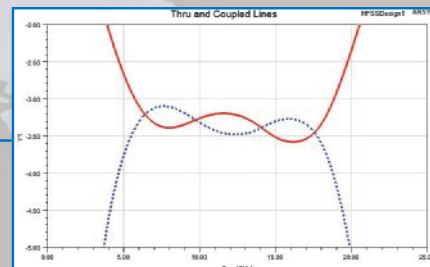
PSC18H17S

2-18 GHz Coupler



PSC18H07S

6-18 GHz Coupler



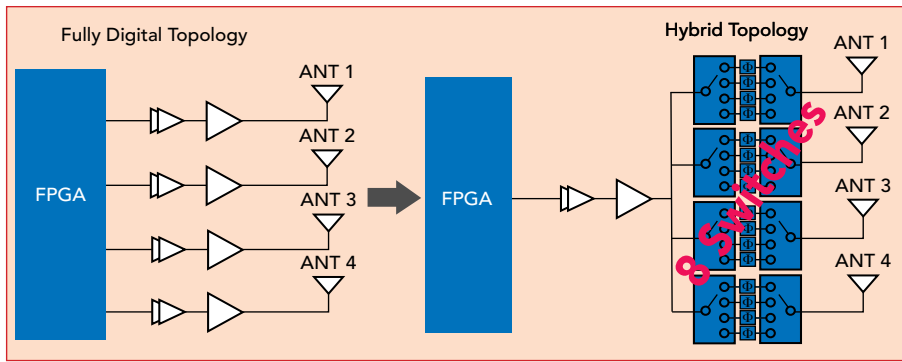
Find out more information about existing, new, and upcoming PolyStrata® Products

Scan for More Information
<https://go.cubic.com/nuvotronics>



Available through

RFMW®



▲ Fig. 10 Comparison of digital and hybrid beamformer topologies.

particularly well-suited for switching applications. Unlike the RRH example, mMIMO AAS base station configurations will present many RFFE SOI opportunities and these are shown in green in Figure 9.

SOI OPPORTUNITIES FOR 5G BEAMFORMERS

Beamforming is essential for high gain and directivity in mMIMO antenna arrays. The three primary beamforming techniques are analog, digital and hybrid. A digital beamformer processes each RF

stream in digital blocks, with a dedicated conversion block per line. An analog beamformer processes a single stream in the baseband, with beamforming accomplished with attenuators and phase shifters at the antenna elements. A hybrid beamformer groups antenna elements into blocks and assigns a digital stream to each block. In this scheme, each element has an analog phase shifter and attenuator. Each beamforming topology has advantages and trade-offs as shown in Table 1.

A digital beamformer offers the highest degree of flexibility, data throughput and coverage since each RF transceiver has a dedicated stream that is processed simultaneously. This requires an enormous amount of processing and a dedicated RF connection to each antenna element. An analog beamformer has the least complexity and power consumption, but it sacrifices flexibility and capability. A hybrid beamformer represents a compromise between the flexibility and performance of a digital beamformer and the simplicity and lower power consumption of an analog beamformer. Figure 10 compares a digital beamformer with a hybrid beamformer, with both having four RF lines. The hybrid beamformer in this example has one digital data stream that is distributed to the antenna elements through four phase shifters and eight switches. This architecture consumes roughly one-quarter the power of an equivalent digital beamformer. The hybrid solution is likely to be smaller, weigh less and have a lower cost than a digital beamforming solution. The disadvantage of this approach is only one independent data stream versus four streams in the digital beamformer.

CONCLUSION

5G mMIMO base station deployment is ramping up and operators and equipment manufacturers are moving away from the legacy components and designs of earlier cellular telecommunication generations. New mMIMO architectures require dramatically different components than legacy base stations and this necessitates an evolution of the wireless technology. The new base stations have many more RF lines, with each line requiring lower RF transmit power. As 5G mMIMO system requirements evolve, OEMs and RF component vendors will collaborate to develop and optimize performance to achieve better power efficiency, size, weight and cost. These efforts will likely require greater levels of integration and fit nicely with the advantages of SOI technologies, setting the stage for an increase in the market share for SOI-based components in wireless base station applications. ■

Optical Communication

Ultra Low Noise XO (OB-U)

- ▶ Tiny Size: 2.5 x 2mm
- ▶ Operation Temperature upto 125°C
- ▶ Tight Stability: $\pm 20/25/50$ ppm
- ▶ Superior Jitter Performance (50fs typ)



Ultra Low Power OCXO (NF)

- ▶ Low Power (75mW typ @ steady stage)
- ▶ Superb Stability: ± 10 ppb @ $-10^{\circ}\text{C} \sim 50^{\circ}\text{C}$
- ▶ Superior Aging Performance: ± 0.5 ppb (Daily)
 ± 50 ppb (Yearly)



Seismic



✉ sales@taitien.com.tw





NEW

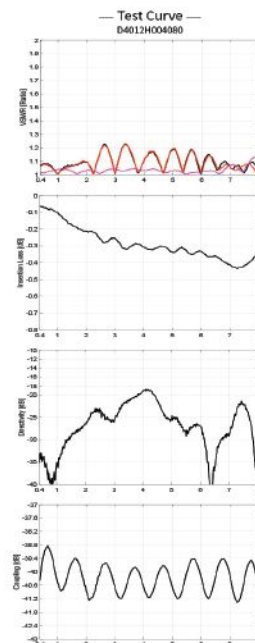
0.4-8GHz HIGH POWER Directional & Dual-Directional Coupler

- High power handling : up to **600W**
- Low VSWR & insertion loss
- Excellent coupling, flatness and directivity which will significantly improve the signal acquisition accuracy
- Environment conditions meet MIL-STD-202F



P/N	CW Power <small>Max.(W)</small>	Nominal Coupling <small>(dB)</small>	Main Line VSWR	Coupling VSWR	Insertion Loss*	Coupling	Flatness	Directivity <small>Min.(dB)</small>
			Max.(1)					
0.4-8GHz Directional Coupler								
D3002H004080	120	30	1.3	1.3	0.8	30±1.0	±0.8	18
D4002H004080	120	40	1.3	1.3	0.8	40±1.0	±0.8	18
D3005H004080	250	30	1.4	1.4	0.7	30±0.9	±1.3	14
D4005H004080	250	40	1.4	1.4	0.7	40±1.0	±1.4	14
D3008H004080	400	30	1.4	1.4	0.7	30±0.9	±1.3	14
D4008H004080	400	40	1.4	1.4	0.7	40±1.0	±1.4	14
D3012H004080	600	30	1.4	1.4	0.7	30±0.9	±1.3	14
D4012H004080	600	40	1.4	1.4	0.7	40±1.0	±1.4	14
0.4-8GHz Dual-Directional Coupler								
D3002HB004080	120	30	1.3	1.3	0.8	30±1.0	±1.0	18
D4002HB004080	120	40	1.3	1.3	0.8	40±1.0	±1.0	18
D3005HB004080	250	30	1.4	1.4	0.7	30±0.9	±1.5	14
D4005HB004080	250	40	1.4	1.4	0.7	40±1.0	±1.6	14
D3008HB004080	400	30	1.4	1.4	0.7	30±0.9	±1.5	14
D4008HB004080	400	40	1.4	1.4	0.7	40±1.0	±1.6	14
D3012HB004080	600	30	1.4	1.4	0.7	30±0.9	±1.5	14
D4012HB004080	600	40	1.4	1.4	0.7	40±1.0	±1.6	14

*Theoretical I.L. Included



More Information-
Scan the QR Code

Fujian MiCable Electronic Technology Group Co.,Ltd

Tel: +86-591-87382856 Email: sales@micable.cn Website: www.micable.cn

The Importance of Crystal Oscillators With Low Phase Noise

Julian Emmerich and Harald Rudolph
KVG Quartz Crystal Technology GmbH, Neckarbischofsheim, Germany

In most areas of our daily lives, data collection and processing, along with large parts of the critical infrastructure have been digitized. Common to all of these efforts is the need for highly accurate reference clocks. Often, crystal oscillators of various designs are used as frequency-determining components. These devices range from simple, unregulated crystal oscillators (XO/VCXOs) to temperature-compensated oscillators (TCXOs) and heated crystal oscillators (OCXOs). One of the most important quality criteria for high performance is the frequency stability of the quartz oscillators. Frequency stability on short time scales can be described by the three quantities: phase noise, jitter and short-term stability. A comprehensive compilation of these three measurement quantities and their interrelation-

ships was published in the January 2023 issue of *Microwave Journal*.

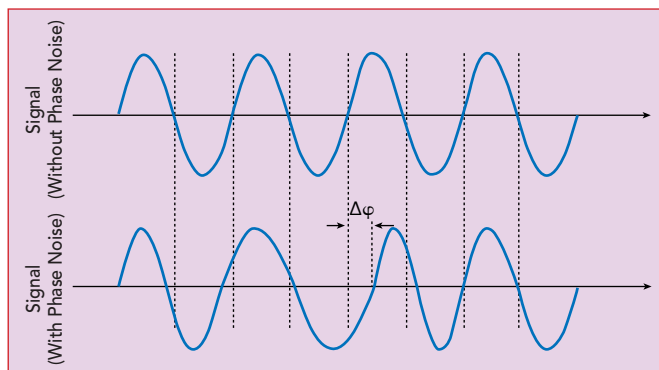
After a short overview of important terms, this article will address the applications of high precision quartz oscillators. Case studies from the fields of measurement technology, data transmission, navigation, radar technology and the processing of audio signals will be considered in detail. In addition to the necessity of extremely low phase noise, the effects of poor phase noise performance are explained for the individual areas.

PHASE NOISE BASICS

Noise effects in electrical circuits are a ubiquitous phenomenon that can be attributed to various physical causes. The noise near the carrier is largely determined by the quality of the oscillator crystal, which acts as a narrowband filter in the range of the resonant frequency in the oscillator circuit.

Figure 1 shows the short-term frequency instabilities that show up in the time domain as a deviation of the zero crossings (phase position) of the actual signal waveform compared to the ideal sinusoid. A modulation of the amplitude is not shown in this figure.

The most important parameters describing phase fluctuations are the phase noise, $L(f)$, the jitter, $\Delta T(\Delta f)$ and the short time stability, $\sqrt{\sigma_y^2(\tau)}$. **Figure 2** shows the phase noise plots of a good TCXO and a very good ultralow phase noise (ULPN) OCXO from KVG Quartz Crystal Technology. "Good" 10 MHz



▲ **Fig. 1** Random, time-dependent phase error ($\Delta\phi$) in the sinusoidal signal.

TTE

INRCORE FAMILY OF BRANDS



EMI/RFI Filters

HIGH-RELIABILITY RF COMPONENTS

For Mission-Critical Applications



ABOUT US

TTE Filters is a leader in the design, development, and manufacture of high quality RF and microwave filters. Our filters are used by OEM's and other organizations around the world to enhance communication and signal processing in critical applications.



610 Series Solder-In Filter

- Utilizes MLC discoidal capacitors, the 'heart' of the filter
- Gold plated case offers superior solderability and conductivity
- Designed to MIL-PRF-28861
- Infinite paths to ground allowing lowest impedance to ground available



620-650 Series Resin Sealed Filter

- Utilizes MLC discoidal capacitors, the 'heart' of the filter
- Silver plated case and hardware offer excellent conductivity
- Designed to MIL-PRF-28861
- Hooked leads available for ease of attachment



710-730 Series Hermetic Filter

- Utilizes MLC discoidal capacitors, the 'heart' of the filter
- Silver plated case and hardware offer excellent conductivity
- Designed to MIL-PRF-28861
- Rated to 15 Amps. Higher Current ratings available as non-hermetic designs

CONTACT US



For more info
SCAN HERE!

+1-716-532-2234

 www.tte.com

TechnicalFeature

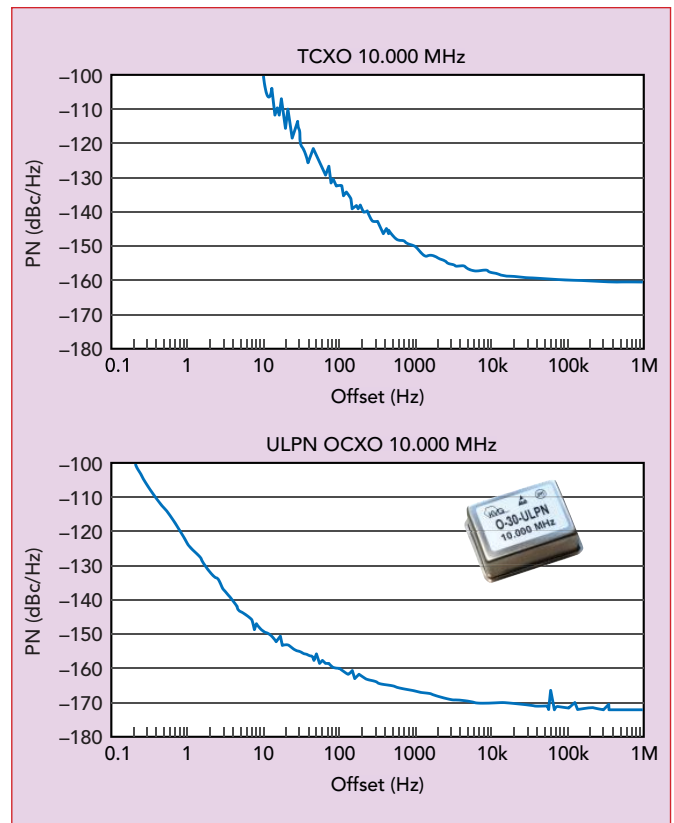
TCXOs achieve phase noise as low as -100 dBc/Hz at 10 Hz offset frequency and a noise floor of -160 dBc/Hz at 100 kHz offset. "Good" ULPN 10 MHz OCXOs are available today with a phase noise of -123 dBc/Hz already at 1 Hz offset and -149 dBc/Hz at 10 Hz offset with a noise floor of better than -170 dBc/Hz.

The short-term stability, mostly expressed in the form of the "Allan Variance" or "Allan Deviation" (ADEV), is much better for good OCXOs than for good TCXOs. "Good" 10 MHz TCXOs have an ADEV in the range of 2×10^{-10} to 2×10^{-11} for a τ of 1 sec. "Good" 10 MHz OCXOs have an ADEV of 2×10^{-12} to 2×10^{-13} , which is about two decades better.

MEASUREMENT TECHNOLOGY APPLICATIONS

Especially in the high frequency range, measurement technology relies on the fact that a signal to be measured is converted to a different and usually lower frequency by mixing with another signal. Low frequency signals are generally easier to analyze and fixed frequency filters and amplifiers can be used to measure the device. The signal to be measured is mixed down to the required frequency range using a local oscillator inside the device.

Figure 3a shows the basic principle of signal mixing in simplified form. In the mixer element, the input signal f_{in} is mixed with the signal of a local oscillator f_{LO} , forming a superposition of the difference signal, $|f_{LO}-f_{in}|$ and the sum signal, $f_{in}+f_{LO}$. If the local oscillator has a phase noise that cannot be neglected, this noise characteristic



▲ **Fig. 2** Phase noise diagrams for a KVG Quartz Crystal Technology TCXO and an ultra-low phase noise OCXO.

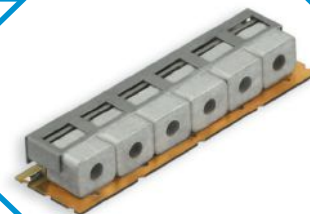


Cutting-edge Connectivity

RF Filter Solutions for Land, Air, and Space Applications

RF Ceramic Filter

- Frequency range from 400 to 6,000 MHz
- Bandpass, notch, diplexed & multiplex
- Surface mount
- Wide operating temperature range
- Light weight, small profile

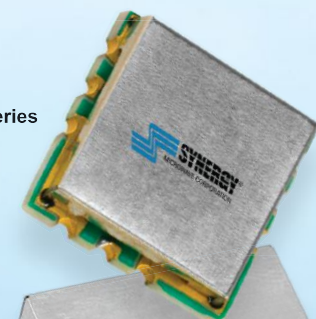


www.smithsinterconnect.com

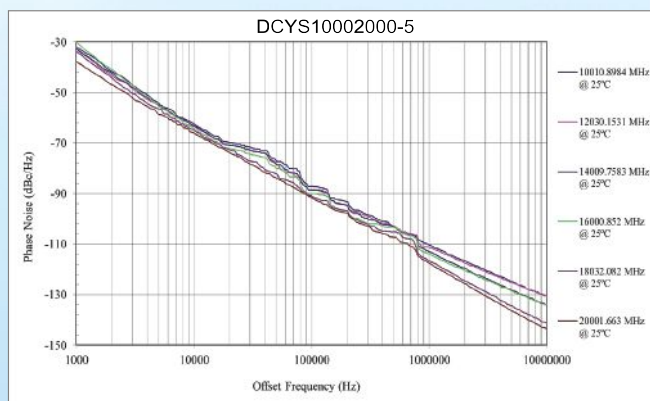
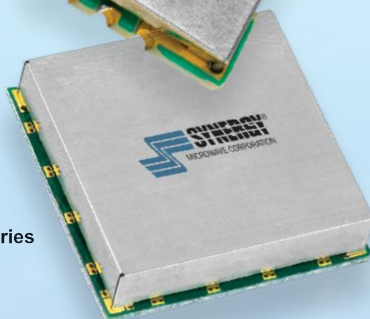
L to K Band **Ultra-Wideband** Voltage Controlled Oscillators

Model Number	Frequency	Phase Noise @ 10 kHz offset	Phase Noise @ 100 kHz offset	Tuning Voltage	Output Power
	(GHz)	(dBc/Hz)	(dBc/Hz)	(V)	(dBm Min.)
DCO100200-5	1 - 2	-95	-117	0.5 - 24	+1
DCYS100200-12	1 - 2	-105	-125	0.5 - 28	+4
DCO200400-5	2 - 4	-90	-110	0.5 - 18	-2
DCYS200400P-5	2 - 4	-93	-115	0.5 - 18	0
DCO300600-5	3 - 6	-78	-104	0.3 - 16	-3
DCYS300600P-5	3 - 6	-78	-109	0.1 - 16	+2
DCO400800-5	4 - 8	-75	-98	0.3 - 15	-4
DCO5001000-5	5 - 10	-70	-95	0.3 - 18	-4
DCYS6001200-5	6 - 12	-70	-94	0.5 - 15	+2
DCYS8001600-5	8 - 16	-68	-93	0.5 - 15	-1
DCYS10002000-5	10 - 20	-53	-79	0.5 - 15	-4

DCO Series



DCYS Series



Features:

- > Superior Phase Noise
- > High Output Power
- > Small Size Surface Mount Package
- > Vcc: 5 volts
- > Future models up to 30 GHz

Talk To Us About Your Custom Requirements.



Phone: (973) 881-8800 | Fax: (973) 881-8361

E-mail: sales@synergymw.com | Web: www.synergymw.com

Mail: 201 McLean Boulevard, Paterson, NJ 07504



Fairview Microwave™

an INFINIT® brand

Smarter Connectivity for Electronic Warfare



New High-Power PIN Diode Switches and Programmable Attenuators

**In-Stock and Shipped
Same-Day**

fairviewmicrowave.com
+1-800-715-4396
+1-972-649-6678

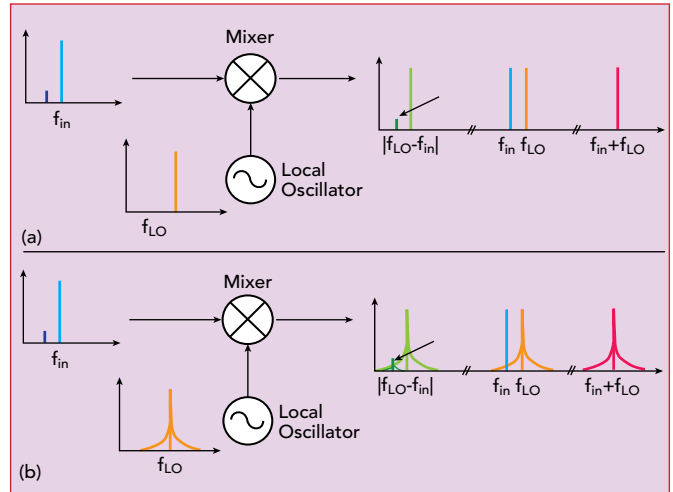
Technical Feature

is also imposed on the mixed signals. As shown in **Figure 3b**, two input signals close to each other are to be analyzed. If the local oscillator signal has a large noise contribution, the smaller input signal disappears almost completely after mixing with the noise of the spectrally broadened stronger signal.

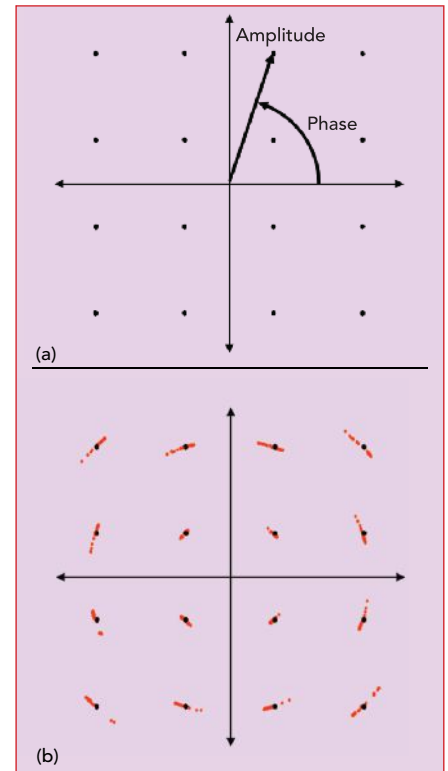
High performance measuring instruments are also used to determine the phase noise of an external signal source. The simplest measurement method is to use a spectrum analyzer since it is a standard measurement device in most electronic laboratories. As long as the phase noise of the spectrum analyzer's internal oscillator is significantly lower than the signal to be measured, a measurement can be performed relatively easily. If the internal oscillator has a comparable or worse noise characteristic than the test object, the effects of signal mixing described above mean that the measurement results are limited by the phase noise of the internal oscillator and may be biased. Only internal reference oscillators with extremely low phase noise must be used in high performance measurement equipment.

DIGITAL COMMUNICATIONS APPLICATIONS

Analogue data transmission has traditionally used amplitude modulation or frequency/phase modulation. Digital data transmission requires far more sophisticated modulation methods to maximize error-free data transmission over the available bandwidth. Current modulation methods for the transmission of digital, discrete signals use a combination of amplitude and phase modulation, with the two degrees of freedom increasing the data transmission rate. Examples of this are amplitude phase shift keying (APSK) or quadrature amplitude



▲ **Fig. 3** (a) Principle of signal mixing in a network analyzer. (b) Effects of mixing an input signal with a noisy LO signal. Source: Revised with permission from Rohde & Schwarz.



▲ **Fig. 4** (a) 16-QAM constellation diagram. (b) Blurring of constellation diagram from phase noise. Source: Revised with permission from Rohde & Schwarz.

modulation (QAM).

Figure 4a shows a constellation diagram for a carrier with 16-QAM modulation. The chart shows 16 different states, with each being described by a unique pair of values consisting of amplitude and a phase angle relative to the coordinate origin. In this modulation variant, phase noise causes a rotation of the



RF and Microwave Adapters In-Stock

Your One Source for RF & Microwave Adapters

Fairview Microwave RF adapter product line includes 746 part numbers, most of which are RoHS and REACH compliant. Fairview Microwave offers 276 in-series RF adapters design and 470 between series adapter designs as well as T and Cross RF adapters. Fairview RF adapters include 41 connector interface types such as SMA, TNC, N and BNC.

Place your order by 6 PM CT, and have your adapters or any other components shipped today.

In Stock & Shipped Same-Day

fairviewmicrowave.com
+1 (800) 715-4396

 **Fairview Microwave®**
an INFINITE® brand

AMPLIFIERS

for all applications

SUPER WIDE BAND 0.01 TO 20 GHz



- > Excellent gain flatness and noise figure
- > Uncompromised input and output VSWR
- > Very low power consumption
- > Miniature size and removable connectors
- > Drop-in package for MIC integration



MODEL	FREQ. RANGE (GHz)	MIN GAIN (dB)	MAX GAIN VARIATION (+/- dB)	MAX N. F. (dB)
AF0118193A AF0118273A AF0118353A	0.1 - 18	19 27 35	± 0.8 ± 1.2 ± 1.5	2.8 2.8 3.0
AF0120183A AF0120253A AF0120323A	0.1 - 20	18 25 32	± 0.8 ± 1.2 ± 1.6	2.8 2.8 3.0
AF00118173A AF00118253A AF00118333A	0.01 - 18	17 25 33	± 1.0 ± 1.4 ± 1.8	3.0 3.0 3.0
AF00120173A AF00120243A AF00120313A	0.01 - 20	17 24 31	± 1.0 ± 1.5 ± 2.0	3.0 3.0 3.0

*VSWR 2 : 1 Max for all models

* DC +5 V, 60 mA to 150 mA

*Noise figure higher @ frequencies below 500 MHz

Custom Designs Available

Other Products: DETECTORS, COMB GENERATORS, LIMITERS, SWITCHES, IMPULSE GENERATORS, INTEGRATED SUBSYSTEMS

Please call for Detailed Brochures



155 BAYTECH DRIVE, SAN JOSE, CA.95134

PH: 408-941-8399 . FAX: 408-941-8388

E-Mail: info@herotek.com

Web Site: www.herotek.com

Visa/Master Card Accepted

Technical Feature

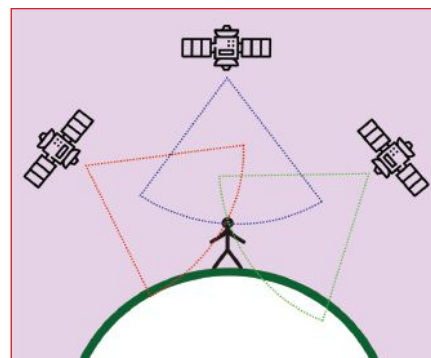
entire constellation diagram, with higher values of phase noise causing a larger rotation of the points. This is seen in **Figure 4b** as a blurring of the exact states of Figure 4a. If this rotation is severe enough, states can be misidentified, leading to bit errors and higher bit error rates. The bit error rate can be reduced by using stable oscillators. Digital communications networks requiring the highest performance will use rubidium or cesium standards or global navigation satellite systems (GNSS)-locked OCXOs. If slightly less performance is acceptable, OCXOs with extremely low phase noise is the likely choice.

NAVIGATION APPLICATIONS

A variety of GNSS are used to determine positions on land and in the atmosphere. Well-known examples of these systems are the Global Positioning System (GPS) in the U.S. and the Galileo system in the E.U. Both systems are available for military and civilian use, although the civilian systems have lower accuracy.

The position is determined by measuring the signal propagation time of a high frequency signal from the satellites to the corresponding receiver. Comparing the transit time differences from at least three satellites allows the exact horizontal position to be calculated. Velocity data is calculated from the frequency shift caused by the Doppler effect of the satellite moving relative to the receiver. This technique requires extremely accurate clocks in the satellites and the GNSS receivers for precise time/frequency measurement. In the satellites, this is realized via cesium/rubidium atomic clocks (GPS) or via hydrogen maser clocks (Galileo), which are regularly calibrated via ground stations distributed worldwide.

Portable GNSS receivers must also incorporate extremely accurate clocks with excellent short-term stability/phase noise. If the receiver clock matches the reference clocks of the satellites exactly, the position can be determined with only three satellite signals. This concept is shown in **Figure 5**. In practice, the data from at least four satellites are required to compensate for the time offset caused by the poor long-term



▲ Fig. 5 Determining position using a GNSS system.

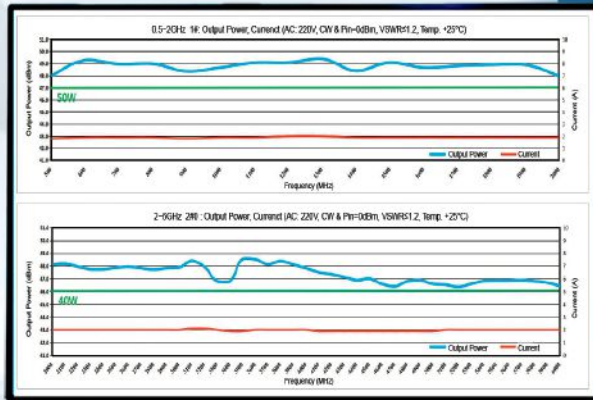
stability of the receiver clocks.

The resolution accuracy of a GNSS receiver is directly related to the noise performance of its internal time reference. Portable receivers for the mass market usually contain only simple XO's or TCXOs for generating the reference frequency, which can result in resolution accuracies in the range of several tens of meters. Professional GNSS receivers work with highly stable OCXOs, which can reduce the error in determining the position to a few centimeters due to the high short-term stability of these OCXOs.

RADAR TECHNOLOGY APPLICATIONS

Depending on the particular area of application, signals with frequencies up to 300 GHz are required for location and speed determination using radar technology. In current systems, the signal is generated by a voltage-controlled oscillator (VCO), which usually has poor frequency stability. To stabilize the signal, the VCO is connected to an extremely stable reference oscillator via a phase-locked loop (PLL). The overall performance of the system, especially the phase noise, is largely determined by the selection of the reference oscillator. In this case, the preference is to design this oscillator as an ultra-low phase noise OCXO.

Using a PLL ensures that the phase noise close to the carrier is determined by the noise of the reference oscillator. Above a certain frequency offset, which is determined by the loop bandwidth of the PLL, the phase noise of the high frequency oscillator dominates. This effect is shown in **Figure 6**, where up to an offset frequency of 100 kHz the



\$18,980 ea.
(1-4 pcs)



NEW **0.5~6GHz** **40W**
Dualband: 0.5~2GHz/2~6GHz

GaN Power Amplifier

- ✓ **High Power**
Psat (Typ./Max.) 48/47dBm @ 0.5~2GHz
47/46dBm @ 2~6GHz
P1dB (Typ./Max.) 45/44dBm @ 0.5~2GHz
44.8/44dBm @ 2~6GHz
- ✓ **Low Harmonic** (2nd/3rd) -20/-30dBc Typ.
- ✓ **Low Spurious** -65dBc Max.
- ✓ **Low VSWR** 1.5:1 Typ.
- ✓ **Turn On/Off Isolation** 90dB
- ✓ Infinite VSWR for No Damage
- ✓ Best Choice for Testing Passive or Active Component
- ✓ High Reliability, Ruggedness,
Built-in Control, Monitoring & Protection Circuits

Micable announced the latest solid state high gain broadband power amplifier **MPAR-005060P44** which covering 0.5~6GHz with output power 40W. It uses state-of-art GaN design technology and can reach higher saturated output power while keeping higher P1dB and better linearity. Its built-in control, monitoring and protection functions improve the reliability of the amplifier. It is designed for applications, such as 5G/ LTE, WIFI and other related system & EMC test.

**Custom designs are available*

More Information-
Scan the QR Code



Fujian Micable Electronic Technology Group Co.,Ltd
Tel: +86-591-87382856 Email: sales@micable.cn Website: www.micable.cn

CERNEX, Inc. & CernexWave

RF, MICROWAVE & MILLIMETER-WAVE COMPONENTS AND SUB-SYSTEMS UP TO 500GHz
5G Ready

- AMPLIFIERS UP TO 160GHz
- FREQUENCY MULTIPLIERS/DIVIDERS UP TO 160GHz
- ANTENNAS UP TO 500GHz



- COUPLERS UP TO 220GHz
- ISOLATORS/CIRCULATORS UP TO 160GHz
- FILTERS/DIPLEXERS/SOURCES UP TO 160GHz
- SWITCHES UP TO 160GHz
- PHASE SHIFTERS UP TO 160GHz
- TRANSITIONS/ADAPTERS UP TO 500GHz
- WAVEGUIDE PRODUCTS UP TO 1THz
- TERMINATIONS/LOADS UP TO 325GHz
- MIXERS UP TO 500GHz



- ATTENUATORS UP TO 160GHz
- POWER COMBINERS/DIVIDERS EQUALIZERS
- CABLE ASSEMBLIES/CONNECTORS UP TO 110GHz
- SUB-SYSTEMS UP TO 110GHz
- DETECTORS UP TO 500GHz
- UMETERS UP TO 160GHz
- BIAS TEE UP TO 110GHz

Add: 1710 Zanker Road Suite 103, San Jose, CA 95112
Tel: (408) 541-9226 Fax: (408) 541-9229
www.cernex.com www.cernexwave.com
E mail: sales@cernex.com

Technical Feature

phase noise is significantly reduced by the use of the reference oscillator, compared to the free-running VCO.

Using the Doppler effect, radar technology can determine the velocity of a moving object from the frequency shift. In a simplified model of a CW radar, a signal of fixed frequency is emitted in the direction of the object to be measured. The electromagnetic wave is reflected by the measured object and travels back to the receiver of the radar unit. Depending on the target's motion relative to the receiver, the frequency of the received signal changes. **Figure 7a** shows the basic Doppler effect concept.

An issue arises if the resulting frequency difference is so small at low velocities that it cannot be measured relative to a noisy carrier frequency as shown in **Figure 7b**. A frequency source with lower phase noise allows for a more accurate velocity determination. For a radar source with a carrier frequency of 1 GHz, an object moving at a speed of 1 km/h produces a Doppler shift of about 1.9 Hz.

AUDIO PROCESSING APPLICATIONS

Sound is a time-dependent, analog mixture of acoustic waves of different frequencies. Audio signals are degraded during analog processing because of noise in components like cables or analog amplifiers. Digital processing of audio signals overcomes some of these limitations. In this process, the analog signal is converted to a digital signal by an

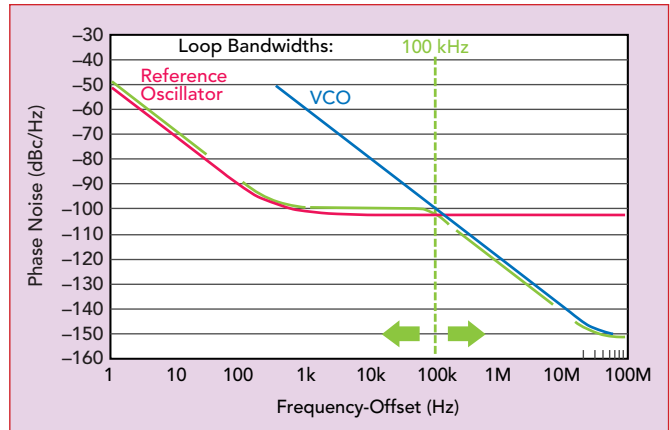


Fig. 6 Phase noise improvement using a reference oscillator. Source: Revised with permission from Rohde & Schwarz.

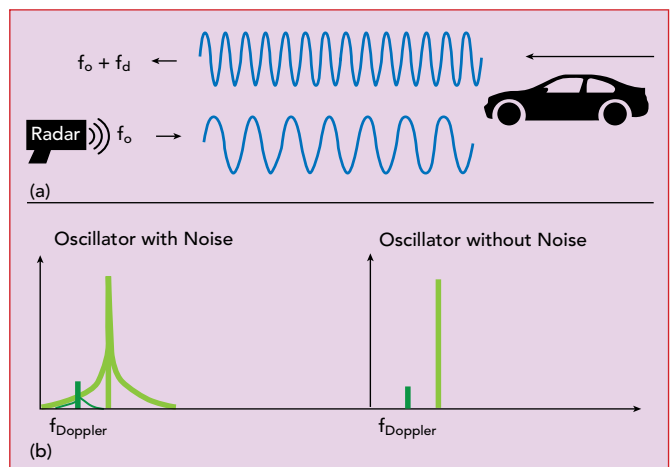


Fig. 7 (a) A radar signal experiences a frequency shift from a moving object. (b) A noisy carrier signal can mask the Doppler-shifted reflected signal.

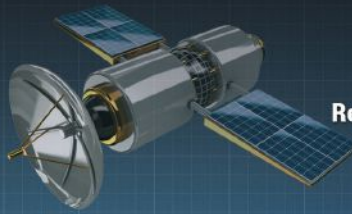
analog-to-digital converter (ADC) before it is digitally processed and converted back to an analog signal by a digital-to-analog converter (DAC). After this conversion, the analog signal is routed to an audio source, like a loudspeaker.

The conversion to the digital audio signal in the ADC takes place at a digital clock rate called the sample frequency f_s , which is usually 44.1 or 48 kHz. According to the Nyquist theorem, these sample frequencies are suitable for digitizing analog signals up to 22.05 or 24 kHz. The sample frequency is usually provided by an internal oscillator called the master clock, which typically oscillates at a multiple of the sample frequency.

The challenge in digitization, especially in the playback of audio signals, is to use a master clock that is as accurate as possible with the lowest possible phase noise. **Figure 8** illus-

RF-LAMBDA

THE POWER BEYOND EXPECTATIONS



ITAR & ISO9000
Registered Manufacture
Made in USA



RF T/R MODULE UP TO 70GHz

DREAM? WE REALIZED IT

LOW LOSS **NO MORE CONNECTOR**
GaN, GaAs SiGe **DIE BASED BONDING**
SIZE AND **WEIGHT REDUCTION 90%**

**HERMETICALLY SEALED
AIRBORNE APPLICATION**

**SATCOM TR MODULE
RX 50GHz TX 22GHz**



TX/RX MODULE
Connectorized
Solution

RF RECEIVER

DC-67GHz
RF Limiter

0.05-50GHz LNA
PN: RLNA00M50GA

RF Mixer

OUTPUT

RF TRANSMITTER

RF Switch 67GHz
RFSP8TA series

RF Filter Bank

0.01- 22G 8W PA
PN: RFLUPA01G22GA

RF Switch 67GHz
RFSP8TA series

0.1-40GHz
Digital Phase Shifter
Attenuator
PN: RFDAT0040G5A

LO SECTION

Oscillator

RF Mixer

INPUT

www.rflambda.com
sales@rflambda.com

1-888-976-8880
1-972-767-5998

San Diego, CA, US
Plano, TX, US

Ottawa, ONT, Canada
Frankfurt, Germany

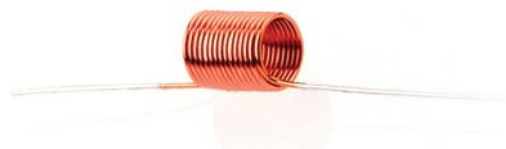


Microwave Components, Inc.
“Let our team at MCI help unwind your coil needs!”

**Specializing in miniature air
coils servicing Defense, Space
and Hi-Rel Markets**

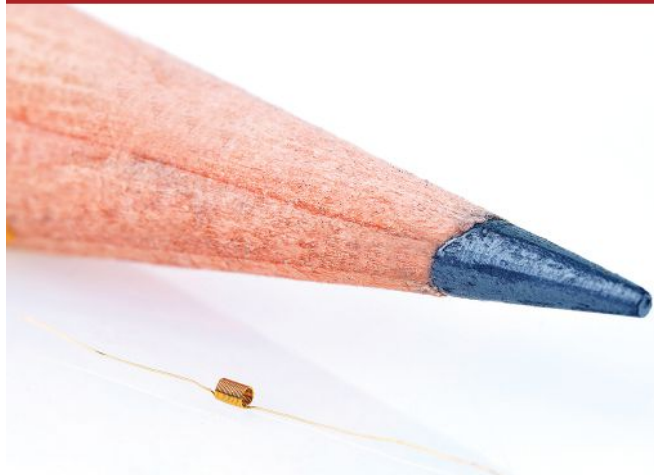


**Veteran Owned
2nd Generation
Small Business**

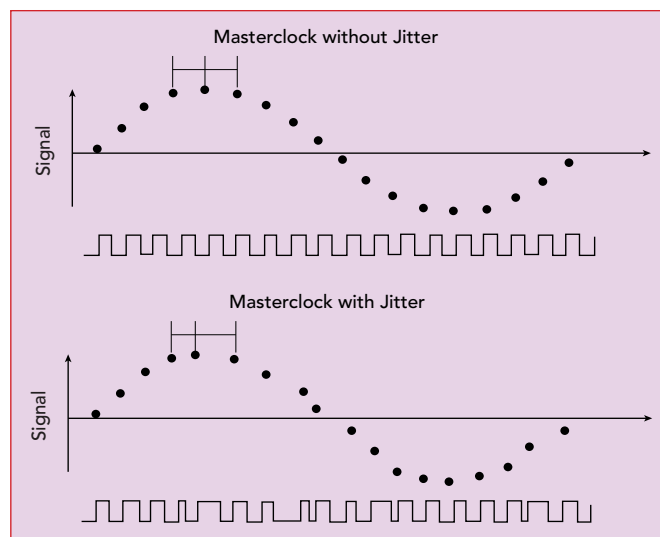


Materials include; bare and insulated gold,
copper, silver, gold plated copper, nickel
copper alloy, and aluminum wire.
Inductances from 1 to 1000+ nH

1794 Bridge St. Unit 21, Dracut, MA 01826
Main: 978-453-6016 Fax 978-453-7132
www.mcicoils.com



TechnicalFeature



▲ Fig. 8 Effects of master clock jitter on signal sampling.

trates the problem of a noisy master clock. During digitization, an accurate master clock ensures exactly equidistant sampling of the analog signal in the ADC, which ensures a faithful reproduction of the input signal at the output. If the master clock is not exactly periodic, this jitter influences the signal sampling. When the sampled signal is converted in the DAC, the result is a distorted output signal that does not faithfully reproduce the input signal and this affects the sound quality at the output.

Low-cost consumer products tend to use low-cost oscillators as the master clock. These oscillators typically have high values for jitter and the sound quality suffers. Professional high performance playback devices for digitally recorded music rely on crystal oscillators with extremely low phase noise to perfect the sound experience in conjunction with high-quality amplifiers and speaker systems.

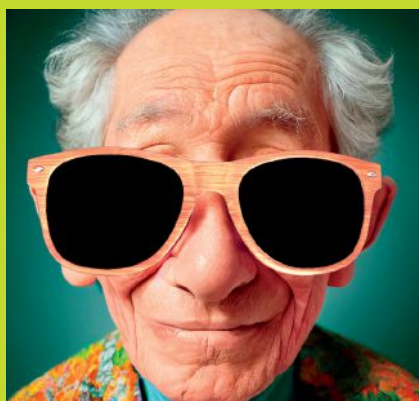
CONCLUSION

High precision frequency sources, such as quartz oscillators with extremely low noise characteristics have become the undisputed standard for electronics in the 21st century. Measurement, data transmission, navigation and audio applications all place the highest demands on the signal sources. While all these applications rely on high performance signal sources, the most important parameters may be different. In telecommunications, the jitter value is important because it can be used to derive the bit error rate during data transmission. In metrology, phase noise is important with oscillators often characterized by a phase noise curve. Depending on the application, near-carrier or far-carrier phase noise may be more relevant, so phase noise values are specified at different distances from the carrier signal. Navigation applications benefit greatly from extremely stable reference clocks. If uncontrolled deviations in the time reference occur at the GNSS receiver, the accuracy of the position determination can deteriorate by one to two orders of magnitude. These and other examples show the importance of highly stable oscillators in a wide variety of applications. ■



**Register
Now!**

IEEE MTT-S International
Microwave Symposium
11-16 June 2023
San Diego 🌻 California



ims-ieee.org





Using Drones to Verify Antenna Performance

QuadSAT
Odense N, Denmark

Satellite communication plays a key role in meeting the relentless demand for connectivity in society. Our industry is seeing a game-changing deployment of infrastructure on the ground and in space, driving the need to maximize the use of the finite radio spectrum. The more efficient we are, the more users will benefit.

QuadSAT has developed a technology to ensure efficient and reliable use of the radio spectrum, allowing satellite operators to deliver more services to more customers while maintaining high quality and availability. This development results from a new method of testing and verifying satellite ground station antennas and RF equipment using drones. By pairing a drone-mounted RF payload with unique pre- and post-flight software, ground station and user terminal satellite antennas can be tested throughout their lifecycle.

The technology was initially offered as a service, which made it possible to bring solutions and perform verification missions for satellite companies. This also provided the opportunity to test the capabilities in operational environments, allowing QuadSAT to hone the product, which is now available both as a product to customers with high

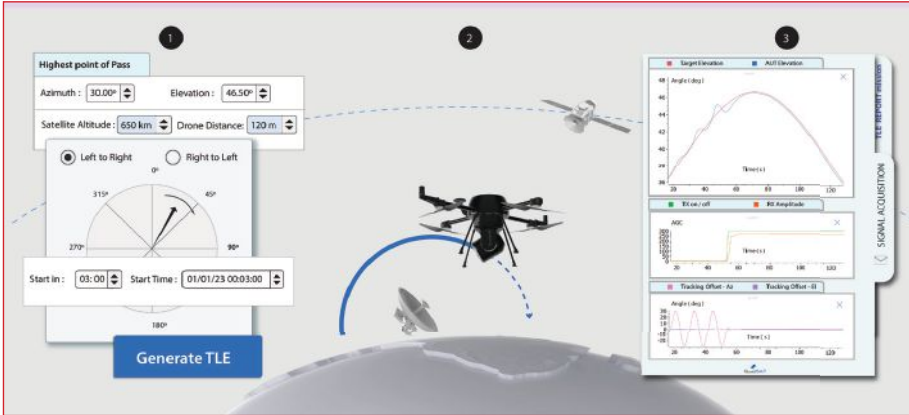
testing demands or service providers and as a service for those users where that is preferable. The goal of this product evolution is to make testing more accurate, accessible and cost-effective for global users.

DRONE-BASED ANTENNA TESTING

Using drones for antenna testing and measurement introduces new capabilities and removes a large amount of complexity normally



▲ Fig. 1 Raster scan process diagram.



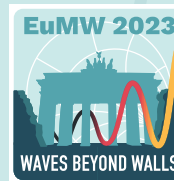
▲ Fig. 2 Antenna tracking verification process diagram.

SIX DAYS

THREE CONFERENCES

ONE EXHIBITION

EUROPE'S PREMIER
MICROWAVE, RF, WIRELESS
AND RADAR EVENT



**EUROPEAN
MICROWAVE WEEK**
Messe Berlin hub27
BERLIN, GERMANY
17th-22nd SEPTEMBER 2023
www.eumweek.com

THE EUROPEAN MICROWAVE EXHIBITION

MESSE BERLIN HUB27,
BERLIN, GERMANY

19TH - 21ST
SEPTEMBER
2023

- 10,000 sqm of gross exhibition space
- Around 5,000 attendees
- 1,700 - 2,000 Conference delegates
- In excess of 300 international exhibitors (including Asia and US as well as Europe)

INTERESTED IN EXHIBITING?

For International Sales:
Richard Vaughan,
International Sales Manager
E: rvaughan@horizonhouse.co.uk

CALL +44(0) 20 7596 8742 OR VISIT WWW.EUMWEEK.COM

associated with this testing. The measurement system can be taken to the site while ensuring a level of accuracy comparable to traditional measurement methods. These tests are fully automated, flexible and location-independent. The system already supports a wide range of measurements critical for ground station equipment, with more features and capabilities in development.

Raster Scans

Measuring the radiation pattern is a fundamental feature of the system and this capability has been used on nearly all our missions. Determining an antenna's performance requires knowledge of the radiation pattern. Without this knowledge, comparing performance between antennas and identifying issues becomes very difficult.

Raster scans are a way of measuring

the radiation diagram on a 3D plane and compared to a single cut it provides much more information about the antenna properties. Their application includes:

- Capturing the radiation diagram of the antenna and painting a clear picture of the main beam and sidelobes
- Determining the state of the antenna performance, i.e., checking for problems with focus, misalignment or manufacturing tolerances
- Measuring and calibrating the pointing mechanism of the antenna
- Tracking changes in the antenna diagram between equipment modifications.

To perform the measurement, the operator plans a flight path for the drone by specifying the width of measurement in azimuth and elevation, as well as the granularity of the measurement lines. The drone flies autonomously on the path and maintains constant pointing and polarization alignment with the antenna under test (AUT). The result is generated by merging the measured amplitude levels with the computed angular position of the drone compared to the AUT. The data points are interpolated and presented in a heatmap or 3D diagram. This process takes around 15 minutes of flight time, with the result generated almost immediately. These results then enable users to:

- Apply contours and determine the 3 dB beamwidth
- Compute beam center
- Verify levels against regulatory masks
- Compare results between measurements
- Extrapolate cuts for regions of interest.

Figure 1 shows an excerpt of the graphical user interface, a representation of the drone flight path, along with a sample output for a representative raster scan for a co-polar and cross-polar measurement. QuadSAT has performed measurements at frequencies from C-Band to Ka-Band for antenna sizes ranging from 40 cm to 17 m and distances from 50 m to 12 km.

Antenna Tracking Verification

Since medium earth orbit (MEO) and low earth orbit (LEO) satellites move relative to Earth, antennas

Charter Engineering offers Largest Configuration of Coaxial Switch Options in the industry

SPDT SWITCHES

(Non-Terminated and Terminated)
SMA, 2.92 mm, Type N, Type SC
connectors



DPDT

(Transfer Switches)

SMA, 2.92mm, Type N connectors



MULTI-POSITION

(Non-Terminated and Terminated)
SMA, 2.92 mm, Type N, Type SC
connectors



Highly Reliable, Repeatable Mil-Standard RF Switches

- Very high power
- DC – 40 GHz
- Low passive intermodulation (PIM)
- Extended temperature range
- Rigorous inspection to meet critically tight tolerances
- Built-to-Order and COTS
- Quotes in hours instead of days
- Fast delivery – most small quantity orders shipped in 4 weeks or less

Visit Us: www.ceiswitches.com

Call Us: 727-525-1025

Email Us: sales@ceiswitches.com



CHARTER ENGINEERING, INC.
Precision RF Switches

a dB Control / HEICO company



© 2023 dB Control Corp

must be able to accurately track the satellite. The rise of new MEO and LEO constellations introduces unknown complexities and being able to quickly evaluate and verify antennas and algorithms can prove to be mission-critical. Identifying potential system issues promptly can help avoid costly delays.

The drone introduces the possibility of simulating satellite passes in real-time, from any direction and at any peak angle. This enables the user to holistically test and verify the tracking and pointing performance of LEO/MEO ground segment antennas, gateways and user terminals. The system can perform make-before-break and handover procedures, along with simulating multiple-beam tracking. It can also simulate real-life scenarios of loss and re-acquisition, launch and early operations or tracking with minimum power levels, sudden changes in frequency, amplitude, modulation type, trajectory, etc. and provide results as well as key performance indicators useful in evaluating the state of the system under test.

To activate this capability, the user locks a precise measurement reference system where the test will be performed. The passes are generated on demand based on peak azimuth and elevation and desired orbital parameters of the satellite. The output, in either TLE or ECEF format, is uploaded into the antenna and the angles and received signal levels are recorded during the pass. A single flight can contain up to four passes and the full-duplex functionality enables the drone to fully simulate a satellite transponder by receiving and storing I/Q data, as well as replaying or transmitting a modulated carrier back to the system under test. The data can be used to perform a calculation of tracking offsets as well as an assessment of the link quality and system reaction in various simulated events. A diagram of this process is shown in **Figure 2**.

Other Measurements

Besides the measurement techniques described, several other measurements are possible. These include wide radiation cuts, absolute gain, cross-polarization discrimination and axial ratio, as well

as environment reflectivity analysis and holistic pointing offset assessment. QuadSAT is constantly upgrading the feature list, working in close cooperation with customers to provide the best solutions.

SUMMARY

QuadSAT has developed this technology to make it cost-effective to test ground station antennas throughout their lifecycle of proto-

typing, qualification, factory acceptance testing, site acceptance testing, calibration and troubleshooting post-deployment. By expanding the service delivery approach to include licensing partners globally, any user can get antenna measurements cost-effectively and responsively, avoiding months of waiting time.

QuadSAT
Odense N, Denmark
www.quadsat.com



NEW 3 GHz & Beyond Products!

- Enables DOCSIS 4.0 & full duplex requirements
- Achieve max RF output power w/ MiniRF passives
- Repeatability & reliability - a MiniRF trademark
- 100% RF test, local design & support



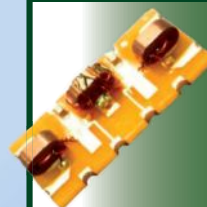
Standard & Custom Components

COUPLERS



1.8 GHz BW
3 & 4 port models
with optional
coupling factors for
Broadband / CATV
Systems.

SPLITTERS



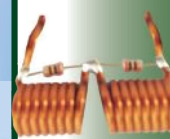
2.5 GHz BW, 2/3&4
way power splitters
designed for both
50 & 75 Ω
applications.

TRANSFORMERS



50 Ω & 75 Ω
supporting a wide
range of applications
with impedance
ratios of 1:1, 1:2,
1:4, 1:8, 1:16.

RF CHOKES



Precision inductors
& chokes with wire
diameters from
0.060~5mm single
& multilayer, air-core,
coil configurations.



For information, samples and sales, contact our
distribution partner RFMW.
www.RFMW.com | sales@rfmw.com



One Box Solution for FR1 Base Station, Small Cell and RF Component Test

Rohde & Schwarz
Munich, Germany

Rohde & Schwarz has introduced the new R&S PVT360A performance vector tester to address high speed, high-throughput testing of all forms of 5G frequency range 1 (FR1) base stations, along with RF component characterization and production testing. The compact single-box instrument provides excellent signal generation performance and analysis capabilities in a small footprint. The R&S PVT360A supports demanding test requirements where minimal error vector magnitude (EVM) is required while accommodating high test throughput. The optional

second generator and analyzer support multiport tests, true MIMO testing or simply double the test capacity.

VSG/VSA SINGLE-BOX TESTER

The R&S PVT360A performance vector tester meets the increasingly demanding requirements for 5G New Radio (NR) FR1 base station and small cell tests, which have resulted from the evolution of the original 3GPP Release 15 specification to Releases 16 and 17. **Figure 1** shows an analysis of a 5G NR signal using the R&S VSE signal analysis software. The instrument's 400 MHz to 8 GHz frequency range covers all 5G FR1 requirements, along with unlicensed frequency bands up to 7.125 GHz in the U.S. The 500 MHz maximum signal bandwidth far exceeds the 5G FR1 maximum of 100 MHz, supporting out-of-band and adjacent channel leakage ratio measurements.

For maximum test throughput, two independent signal generators and analyzers enable fast parallel measurements, with each channel supporting eight parallel full-duplex test ports. For each channel, the output test signal can be broadcast to all eight ports. Input ports are switched in less than 10 microseconds for sequential analysis of either parallel or multiport devices. Transmit-



▲ **Fig. 1** Graphical user interface of the PVT360A.



IEEE MTT-S International Microwave Symposium
11-16 June 2023
San Diego  California
San Diego Convention Center



Exhibit at IMS2023

Showcase Your Coolest Ideas Under the Sun

Join thousands of RF & microwave professionals from across the globe
Strengthen existing business relationships and meet new contacts
Display your company's innovative solutions, products and services



480+
Exhibitors

This
Way to
IMS2023!

WELCOME
TO
SAN DIEGO

Book Your Booth Space Today
ims-ieee.org



FEATURED

WHITE PAPERS

The information you need, from industry experts

ALTAIR

Large Platform Co-site Interference Mitigation

ALTUM RF

Cost-Effective Front-End Components for X- and Ku-Band Phased Array RADAR

Coilcraft

Using Baluns and RF Components for Impedance Matching

RichardsonRFPD

An Arrow Company

Stop the Clock, How Advances in Quartz Crystals and Silicon Germanium BiCMOS Circuits Simplify High Speed Clock Generation for RF Data Converters

ROHDE & SCHWARZ

Make ideas real

Understanding EMI Precompliance Testing

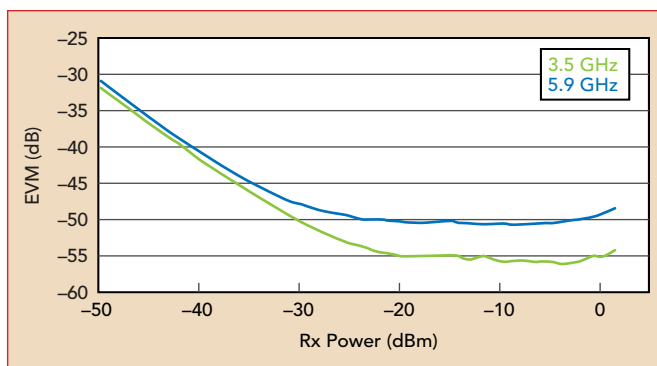
SKYWORKS

Holdover Plays an Important Role in the Network

Look for additional content from:

Check out these new online Technical Papers featured at MWJournal.com

ProductFeature



▲ **Fig. 2** Measured EVM of a 5G NR downlink TM 3.1 100 MHz signal.



▲ **Fig. 3** R&S PVT360A in a component test setup.

ter and receiver tests can be carried out in parallel and the R&S PVT360A optimizes test sequences to minimize idle time between result processing. With the second channel installed, users can run true MIMO 2x2 tests

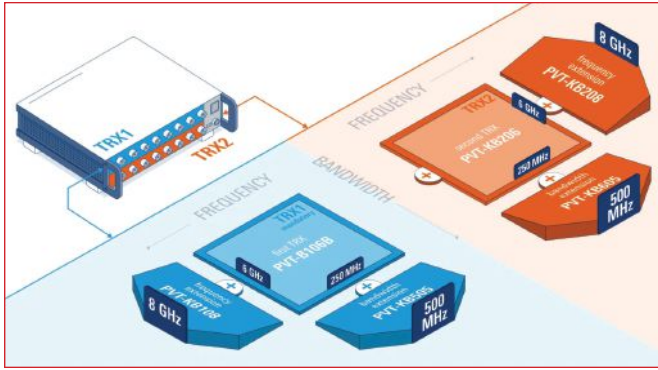
with the signal paths tested in parallel, not sequentially. The optional smart channel mode divides the R&S PVT360A into a maximum of eight separate virtual instruments. Each of these virtual instruments has an independent VISA address and a separate tab in the GUI, allowing different measurements on each channel. The generator and analyzer are shared across the virtual instruments, with optimized resource scheduling for all calculations and processing.

BASE STATION AND SMALL CELL TEST

For most production test requirements, standard-compliant waveforms for 5G NR release 15, 16 and 17 support all typical base station transmitter and receiver tests such as EVM, output power or frequency error. The R&S PVT360A achieves EVM results as shown in **Figure 2**. The measurements can be operated fully in parallel for up to two transmitter tests. If a higher number of devices under test or ports are connected, the tests run in quasi-parallel with automated scheduling of resources. Multi-component carriers can be tested and the optional two pairs of vector signal generators and analyzers enable real MIMO measurements. The graphical representation of the measurement results gives a comprehensive overview of the signal characteristics. The second signal generator benefits users performing receiver tests. Wanted and interfering signals for in-band blocking and in-channel selectivity tests can be generated, as required, in one box.

COMPONENT TEST AND IN-DEPTH CHARACTERIZATION

For active component testing as shown in **Figure**



▲ Fig. 4 Keycode options for hardware extensions.

3, the R&S PVT360A provides signal generation and analysis capabilities for both cellular and WLAN standards. When testing components with modulated signals, their characteristics can be validated under realistic conditions. Good EVM performance of the R&S PVT360A signal generator provides high precision test signals that create minimal measurement uncertainty in component characterization applications, providing developers with the highest possible performance. If additional signals are required, customized waveforms may be created using WinIQSIM2, a PC-based waveform creation program. For additional analysis, the R&S VSE vector signal explorer PC-based signal analyzer software can be utilized.

Measurements performed during the characterization phase can be stripped down and carried out on the box for fast production testing of key parameters. The results can then be correlated with more extensive tests performed during the characterization phase. The hardware-accelerated list mode provides outstanding measurement speed and automation options in production.

ENHANCED TESTING IN PRODUCTION ENVIRONMENTS

Designed for remote operation, the R&S PVT360A performance vector tester offers automated capabilities for easy integration into testbeds. Preconfigured test routines consistent with 3GPP requirements simplify the test process. The intuitive web user interface gives an overview of all signal generation and measurement parameters and capabilities for manual configuration.

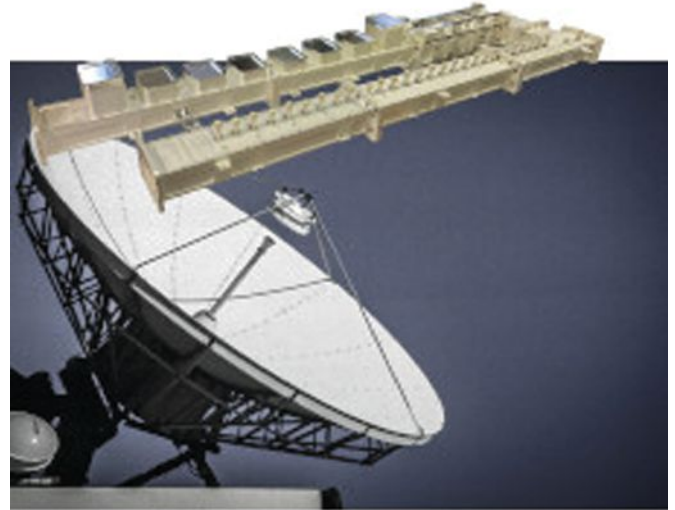
To cover the full range of requirements in the extremely price-sensitive production test market with a single instrument, the R&S PVT360A option concept uses a single generator and analyzer to support eight test ports with frequencies ranging from 400 MHz to 6 GHz and a bandwidth of 250 MHz. In the complete twin-channel configuration, each port has a frequency range of 400 MHz to 8 GHz with a 500 MHz bandwidth. As illustrated in **Figure 4**, all extensions are by key-code and they can be installed instantly. The new R&S PVT360A performance vector tester is now available from Rohde & Schwarz.



Rohde & Schwarz
Munich, Germany
www.rohde-schwarz.com/product/pvt360a



**HIGH POWER WAVEGUIDE
DIPLEXERS LOW INSERTION
LOSS AND HIGH ISOLATION**



sales@exceedmicrowave
www.exceedmicrowave.com

**FREQUENCY
CONTROL
PRODUCTS**

**Made in
Germany**



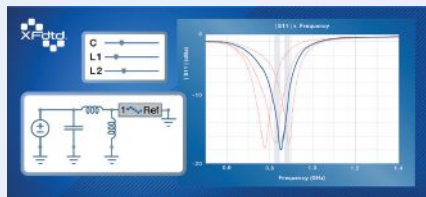
Quartz Crystal Technology GmbH

75 YEARS OF EXPERIENCE

Waibstadter Strasse 2 - 4 | 74924 Neckarbischofsheim (GER)

Phone: +49 7263 648-0 | Fax: +49 7263 6196

Email: info@kvg-gmbh.de | www.kvg-gmbh.de



The latest version of XFDTD® 3D Electromagnetic Simulation Software introduces matching network tuning, which enables users to easily adjust component values to meet design goals and understand the behavior of a circuit. The tuning functionality is part of a new analysis workbench in XFDTD's schematic editor, broadening the software's toolset for comprehensive matching network design. The workbench's intuitive sliders enable rapid manipulation of inductor and capacitor values to reveal the impact of various combinations in real time. This immediacy makes additional analysis effortless while resulting in a more thorough understanding of

XFDTD® Software Update Introduces Tuning Functionality for Comprehensive Matching Network Design

how the circuit will behave. Intermediate states may be saved without changing the base schematic; final states can then be added to a new operating mode or committed to the schematic permanently.

In addition to simplifying the process of identifying a favorable match that meets or exceeds performance requirements, the tuning functionality is valuable for analyz-

ing the matching network's sensitivity to component tolerance. Use cases include fixed band matching for devices that use a single band as well as tunable matching for devices that must switch between bands.

VENDORVIEW

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

COST-EFFECTIVE HERMETIC MICRO D CONNECTORS

Standard 9 to 51 pin configurations available
or let us design to your custom requirements



SPECIAL HERMETIC PRODUCTS, INC.

Hi-Rel By Design

CONTACT US TODAY

(P) 603-654-2002 (F) 603-654-2533

www.shp-seals.com email: sales@shp-seals.com

CERTIFIED ISO 9001:2008



VNA Provides Component Analysis up to 26.5 GHz

The continuous growth of radio and cellular networks means increases in data traffic and data rates, driving the need for high performance measurement technology. Analyzing and verifying components and the network are important tasks during the development phase. High frequency vector network analyzers (VNAs) are the key measuring device for this work.

The SNA5000A Series VNAs can analyze 2-port devices up to 26.5 GHz and 4-port devices up to 8.5 GHz. All single-ended and differential S-parameter measurements are available by pressing a button. The 125 dB dynamic

range allows, for example, a precise analysis of the stopband of a filter without losing sight of the passband. The flexible multi-window function combined with a 12-in. touchscreen enables a concise representation of all results on one screen. Bias tee inputs simplify the setup to characterize devices that need DC-bias voltage.

The SNA5000A series also includes multiple options for key applications. An optional scalar mixer measurement (SMM) mode makes analyzing frequency conversion devices like mixers easy and fast. The analyzer series offers enhanced time-domain analysis as an option to further increase this flexibility. This mode allows an eye diagram to

be displayed and it supports jitter performance measurements. This option makes the analyzer well-suited for cable and connector performance characterization measurements. The SNA5000A series can also be equipped with a spectrum analysis mode, which can be used in parallel on every port. The advanced and intuitive user interface and versatile capabilities make the SNA5000A a great choice for every bench while its solid RF performance, ease of use and convenient size make it great for everyday RF testing.

SIGLENT Technologies
Solon, Ohio
<https://siglentina.com>



M WAVE DESIGN CORPORATION

designs and manufactures in the U.S. and provides a broad range of custom passive microwave hardware from 100MHz to 50GHz.



M WAVE DESIGN CORPORATION is ISO9001 certified, ITAR compliant and provides superior customer service. **We are proud to celebrate our past 30 years and to support you in the next 30.**

SUPPLYING HIGH-PERFORMANCE PASSIVE RF & MICROWAVE COMPONENTS SINCE 1988



HIGH-POWER WAVEGUIDE ISOLATORS

S band through R band waveguide isolators covering S-Band (2 GHz) through U-Band (50 GHz); our Isolator product line provides state of the art power handling and insertion loss. With available options of; high power terminations, multiple interface flanges, miniature versions, and integrated Forward and Reverse power monitoring.



COAXIAL CIRCULATORS

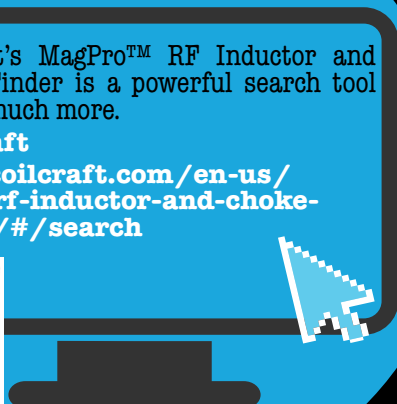
Our full line of Coaxial circulators from 100 MHz to 40 GHz feature high power ratings (> 100 Kw), and low insertion loss (< 0.10 dB) depending upon the application. With many connector interfaces & package options, we can provide a solution to your needs.

RF Inductor Choke Finder and Analyzer

Coilcraft's MagPro™ RF Inductor and Choke Finder is a powerful search tool and so much more.

Coilcraft

www.coilcraft.com/en-us/tools/rf-inductor-and-choke-finder/#/search



Infineon Kicks Off Smart Power Fab in Dresden

Infineon is starting construction of its new plant for analog/mixed-signal technologies and power semiconductors. After extensive analysis, Infineon decided on the Dresden site, with completion set for 2026.

Infineon Technologies AG

www.infineon.com

New Video from Exodus

Watch Exodus Advanced Communications' new video about their low noise, low frequency, broadband, millimeter, pulse and high frequency amplifiers.

Exodus Advanced Communications

www.bit.ly/3JjYEwN



An Introduction to RF & Microwave Thin-Film Filter Technology

Finding the right filter for frequency ranges above the 3 GHz range is a perennial challenge for RF system engineers, learn some tips in this blog post.

Mini-Circuits

<https://blog.minicircuits.com/an-introduction-to-rf-microwave-thin-film-filter-technology/>



Radix™ 3D Printable Dielectrics

Explore new degrees of freedom and creativity in your RF designs. View the sponsored video today.

Rogers Corporation

www.youtube.com/watch?v=3YMRfwOuWlw



Poster: How High Precision GNSS Enables New Automotive Applications

This poster shows the different types of error sources and explains how high precision GNSS calculates and transmits error correction data to vehicles, enabling new automotive applications for GNSS.

Rohde & Schwarz

<https://bit.ly/3KPWOA8>



NEW PRODUCTS

FOR MORE NEW PRODUCTS, VISIT WWW.MWJOURNAL.COM/BUYERSGUIDE
FEATURING **VENDORVIEW** STOREFRONTS

DEVICES/ COMPONENTS/MODULES

Reflective Switch Gates G-Band Signals



Model SKS-1442243035-0505-R1-M is a single pole, single throw (SPST) reflective switch that operates from 140 to 220 GHz. The switch

exhibits insertion loss of 3 dB in the ON state with typical isolation of 35 dB in the OFF state. In-line WR-05 waveguide ports have UG-387/U-M anti-cocking flanges. An SMA connector accepts the TTL-level control signal. The switching speed is 100 ns. Bias voltages of +1 and -2 V are required. The switch measures 1.0 x 1.0 x 0.75 in.

Eravant

www.eravant.com

S-Band Diplexer



Exceed Microwave's custom designed S-Band diplexer provides high isolation of > 120 dB with low insertion loss

of < 0.3 dB. It uses dual mode resonators for low insertion loss and sharp near-band rejection. The transmit channel is designed to handle 10 kW minimum. Custom designed filters and other passive RF/microwave components are available.

Exceed Microwave

www.exceedmicrowave.com

Common Mode Choke Inductors



Vanguard Electronics, under the iNRCORE family of brands, announced its new XTCMN5 Series common mode choke inductors. The

XTCMN5 Series is designed to operate in extreme environments and work in frequency ranges from 100 to 600 KHz+, making them ideal parts for GaN-based power supplies as well as traditional switching supplies. These parts feature a compact low profile, ideal for automatic placement as well as demands of high shock and vibration. Different electrical values and termination finishes are available.

iNRCORE

www.inrcore.com

mmWave Controlled Components

General Microwave offers a wide range of mmWave products operating in the 18 to 40 GHz frequency range including catalog attenuators, switches and phase shifters as

well as integrated microwave assemblies. If it is a standard catalog unit or a highly customized mmWave product designed specifically for high performance, General Microwave can provide products to support your requirements.

Kratos/General Microwave Corp.

www.kratosmed.com

USB SP4T Switch



Mini-Circuits' model USB-1SP4T-A673 single pole, four throw (SP4T) absorptive

switch steers 0.1 to 67 GHz with 2 ms switching speed. Typical insertion loss is 5.8 dB to 40 GHz and 9.8 dB to 67 GHz. Isolation between ports is typically 35 dB to 60 GHz and 30 dB to 67 GHz. Featuring USB port, 1.85-mm female connectors and integrated microcontroller, the switch measures just 4.874 x 0.984 in. (123.8 x 25.0 mm) and can handle as much as +22 dBm input power.

Mini-Circuits

www.minicircuits.com

New Bias Tees



Pasternack has introduced an innovative series of bias tees addressing a variety of applications, including test

and measurement, research and development, optical communications, satcom and more. Pasternack's expanded bias tee offering includes various design configurations that cover a broad range of frequencies from 12 KHz to 40 GHz, high DC current and voltage handling up to 7 amps and 100 V, and high port isolation of 30 dB typical. A variety of coaxial packaged configurations are available.

Pasternack

www.pasternack.com

Switch Filter Banks



Switch filter banks are readily customized for filters centered between 0.5 and 18 GHz, with bandwidth from 1 to 100

**NORDEN
MILLIMETER**

Norden Millimeter Designs and Manufactures
RF Multipliers, Amplifiers, Converters, and Transceivers
Between 0.5-110 GHz

See the Specs for our VPX Transceiver.
Visit www.NordenGroup.com/VPX
or Contact Our Sales Team for Our
Entire Product Line

Sales@NordenGroup.com
www.NordenGroup.com
530-719-4704

NewProducts

percent. Digital control can be configured to use TTL or COMS logic with inputs provided through a variety of methods including a micro-D connector or hermetic pins. Typical design considerations include minimizing package size, switching speed, video leakage, phase noise, impulse response, high power and high isolation. Our modules are packaged in a rugged housing with hermetical seals and internal potting in order to provide high-reliability in difficult environments. Applications include military radio, radar, SIGINT, electronic warfare and satcom.

Q Microwave
www.qmicrowave.com

High-Power, High Directivity Directional Couplers



RLC Electronics' high-power, high-directivity directional couplers offer accurate coupling (± 1.0 dB), low insertion loss (0.1 to 0.35 dB maximum) and > 35 dB directivity in both directions. These high-power couplers are offered with 500 to 1000 W average power handling up to 18 GHz, as well as 100 W versions up to 40 GHz. Couplers are provided in both single- and dual-directional construction, typically over a two octave bandwidth or less. RLC can utilize SC or 7/16 connectors on the main line, should this be needed to meet customer designs.

RLC Electronics
www.rlcelectronics.com



Microwave Journal

Frequency Matters.

AT Series of RF Chip Attenuators from DC to 20 GHz

VENDORVIEW



RF chip attenuators are components used in communication systems to reduce the strength of a signal passing

through it. They play a crucial role in protecting systems from receiving a signal with a power level that is too high to process. The range being introduced from Smiths Interconnect is significant because it offers a high frequency of DC to 20 GHz which is required for use in key commercial and space applications.

Smiths Interconnect
www.smithsinterconnect.com

CABLES & CONNECTORS

High Voltage 10 kV/20 kV Connectors and Adapters

VENDORVIEW



Fairview Microwave released a series of 10 kV and 20 kV connectors and adapters. They are suitable for a wide range of uses, including imaging inspection,

test and measurement, medical and aerospace applications. This new line of hermetically sealed 10 kV and 20 kV connec-

tors and adapters offers decreased rates of off-gassing and diffusion. Made with rugged brass bodies and nickel plating, these high voltage connectors and adapters are resilient and long lasting.

Fairview Microwave
www.fairviewmicrowave.com

Multipin Hermetic Connectors



SHP manufactures a select group of both RF and rectangular multipin hermetic connectors for various military and commercial temperature environments. These competitively priced connectors are unique in that they are specifically designed and optimized for high-reliability in specific packaging materials. The result is significant savings by elimination of the common failure modes associated with the "one size."

Special Hermetic Products Inc.
www.shp-seals.com

AMPLIFIERS

Exodus AMP2080D, 10 kHz - 250 MHz, 500 W

VENDORVIEW



Exodus AMP2080D is ideal for broadband EMI-Lab applications. Class A/AB linear design for all modulations and

Catch up on the latest industry news with the bi-weekly video update

Frequency Matters from Microwave Journal @ www.microwavejournal.com/frequencymatters

Novel Design and Manufacturing Techniques Revitalize mmWave TWTs

The Importance of Crystal Oscillators With Low Phase Noise



Microwave Journal
Frequency Matters.

GaN-Based Devices for Advanced RF Applications Puts Technology Building Blocks in the Spotlight

RF SOI Enables 5G mMIMO Active Antenna Systems



Sponsored By
ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

INTEGRA
RF POWER DEVICES

NewProducts

industry standards. Covers 10 kHz to 250 MHz, produces 500 W minimum, 700 W typical with 57 dB minimum gain. Excellent flatness, optional monitoring parameters for forward/reflected power indication, VSWR, voltage, current and temperature sensing for superb reliability and ruggedness. Integrated in the compact 8U chassis weighing approximately 45 kg.

Exodus Advanced Communications
www.exoduscomm.com

High Linearity, High Power Amplifier



M1Cable introduces the new 100 W solid-state high gain wideband power amplifier MPAR-

010060S50 with the latest high-power RF GaN transistors, built-in control, monitoring and protection functions. It is designed for applications, such as 5G/LTE, Wi-Fi and other related system and EMC test. Custom designs are available.

Fujian Micable Electronic Technology Group Co. Ltd.
www.micable.cn

High Gain, Broadband, Low Noise Amplifier



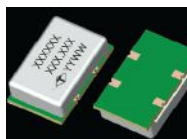
Model ABL1800-01-4525 is a high gain three stage MMIC based low noise amplifier module operating in the

frequency range from 0.1 to 18.0 GHz. It offers 45 dB of linear gain and 2.5 dB typical noise figure with excellent gain flatness and input/output return loss. The unit has a built-in voltage regulator and operates with a single DC power supply voltage. The package size of the amplifier is $1.9 \times 1.0 \times 0.4$ in.

Wenteq Microwave
www.wenteq.com

SOURCES

VLCU and VLEU VCXO



Taitien Electronics introduced a new VLCU and VLEU VCXO product series that has superior phase noise and low G-sensitivity performance.

The noise floor is as low as -175 dBc/Hz and is ideal for applications like testing, optical communication, satellite, 5G base station, high-definition video broadcasting system, etc. The VLCU/VLEU series VCXO supports 50 to 150 MHz, clipped sine wave or CMOS output, 3.3 or 5 V power supply, -40°C to 85°C operation temperature and is sized at $14.0 \times 9.0 \times 3.6$ mm.

Taitien Electronics
www.taitien.com

TEST & MEASUREMENT

Vector Network Analyzer



The SIGLENT SNA5000A series of vector network analyzers (VNAs) have a frequency range of 9 kHz to 8.5 GHz and 100 kHz to 26.5 GHz,

which support 2/4-port scattering parameter, differential parameter and time-domain parameter measurements. The SNA5000A series of VNAs are effective instrumentation for determining the Q factor, bandwidth and insertion loss of a filter. They feature impedance conversion, movement of measurement plane, limit testing, ripple test, fixture simulation and adapter removal/insertion adjustments.

Siglent
www.siglentna.com

PCI Digitizers



Spectrum Instrumentation launched the fastest digitizers in the 33-year company history. The cards offer a stunning

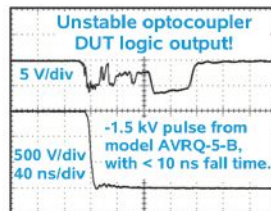
combination of ultra-fast 10 GSPS sampling speed, 12-bit vertical resolution and market-leading 12.8 Gbps data streaming over the PCIe bus. The one- and two-channel cards also feature front-end circuitry with over 3 GHz bandwidth and up to 16 Gb (8 GS) of on-board memory.

Spectrum Instrumentation
www.spectrum-instrumentation.com

MICRO-ADS

TRANSIENT IMMUNITY TESTERS

The Avtech AVRQ series of high-voltage, high-speed pulsers is ideal for testing the common-mode transient immunity (CMTI) of next-generation optocouplers, isolated gate drivers, and other semiconductors.

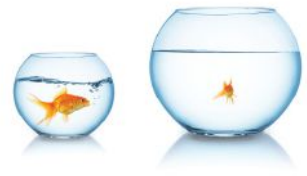


Avtech Electrosystems Ltd.
http://www.avtechpulse.com/



Nanosecond Electronics Since 1975

One Size Does Not Fit All



RF connectors and adapters that fit your needs.



The Answer to Your RF Connector and Adapter Search

CUSTOMRFCONNECTORS.COM
812.526.8801

KR Electronics
www.krfilters.com
ISO 9001:2008 Certified

Custom & Standard Filters
40+ Years of Military & Commercial Applications

Bandpass	Lowpass
Anti-Aliasing	Notch
Highpass	Root Cosine
Video Filters	Equalizers
Diplexers	Linear Phase
Delay Equalized	Absorptive
Surface Mount	Matched

KR Electronics, Inc.
Avenel, NJ
www.krfilters.com

sales@krfilters.com
Phone 732.636.1900
Fax 732.636.1982

RF Amplifiers, Isolators and Circulators from 20MHz to 40GHz

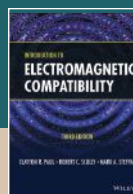
- Super low noise RF amplifiers
- Broadband low noise amplifiers
- Input PIN diode protected low noise amplifiers
- General purpose gain block amplifiers
- High power RF amplifiers and broadband power amplifiers

- RF isolators and circulators
- High power coaxial and waveguide terminations
- High power coaxial attenuators
- PIN diode power limiters
- Active up and down converters

Wenteq Microwave Corporation
138 W Pomona Ave, Monrovia, CA 91016
Phone: (626) 305-6666, Fax: (626) 602-3101
Email: sales@wenteq.com, Website: www.wenteq.com



Review by: Whitney Lohmeyer



Bookend

Introduction to Electromagnetic Compatibility

By Clayton R. Paul, Robert C. Scully and Mark A. Steffka

“Introduction to Electromagnetic Compatibility, Third Edition” is an ideal textbook for every university undergraduate enrolled in an EMC course, for practicing electrical engineers dealing with interference issues or for those wanting to learn more about electromagnetic compatibility to become better product designers. The authors provide a well-written, easily digestible, yet thorough reference that demystifies EMC through the explanation of fundamental theory around spectrum, transmission lines, antennas, radiation, crosstalk and shielding, along with Federal Communications Commission regulations – why they exist and how compliance tests are performed. Included in the appendix is an intro to

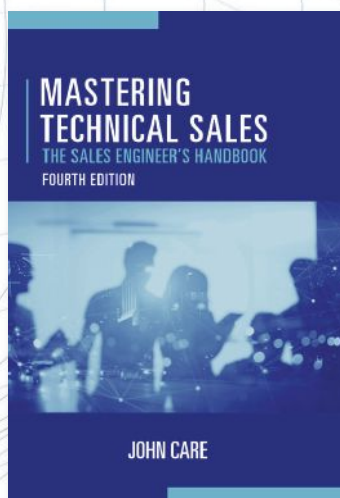
electrical circuit analysis and lumped-circuit approximate models for transmission lines using tool kits like PSPICE or LTSPICE, which may be used for EMC analysis. Future editions of this text could introduce computational electromagnetics with techniques like MoM, FIT, FEM and tools like HFSS, CST or FEKO and contextualize their use by delineating specific modeling methods appropriate for various analyses. The text culminates with a chapter on systems-level EMC design strategies that elegantly incorporate and synthesize material presented in previous chapters. Most electronic products are designed to achieve metrics related to reliability, accuracy, cost, weight or some combination of these qualities. EMC has tra-

ditionally posed a challenge to each of these metrics, especially cost. While this book will not magically solve every EMI issue, in the words of Dr. Paul himself, “Successful EMC design of a product depends on the early and continuous application of the principles outlined in the text.”

ISBN: 978-1-119-40436-1

848 Pages

To order this book, contact:
Wiley (October 2022)
www.wiley.com



Mastering Technical Sales: The Sales Engineer's Handbook, Fourth Edition

John Care

Hardcover • 420 pp. • 2022
ISBN: 978-1-63081-872-2

\$98 / £85

LEARN

TO NAVIGATE A COMPLEX AND EVER-CHANGING
TECHNICAL SALES ENVIRONMENT

- ▶ Master the unique role of the Sales Engineer, from the broad picture to the nuances of the job
- ▶ Become an effective bridge-builder between the business/commercial interests and the technical details that support the sale
- ▶ Improve your skills and increase your value to the sales team
- ▶ Integrate global practices into your day-to-day activities
- ▶ Increase your ability think on a more strategic level

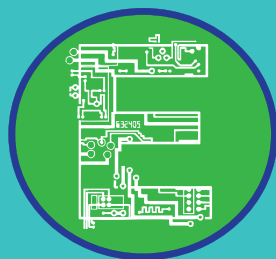


ARTECH HOUSE

BOSTON | LONDON

Order at ArtechHouse.com

PRACTICAL BOOKS FOR ENGINEERING PROFESSIONALS



LEARNING CENTER

Presented by: **Micro
Journal**

NEW

4/12

**Fully Integrated Ideal Switch Solution
Meets PCIe 6.0 Requirements with HSIO
Loopback**

Sponsored by:



4/13

Mixed Technology Filters

Sponsored by:



4/18

**Oscilloscope-Based Impedance
Measurement**

Sponsored by:



4/25

**Large Platform Co-site Interference
Mitigation**

Sponsored by:



ONLINE PANEL SERIES

4/19

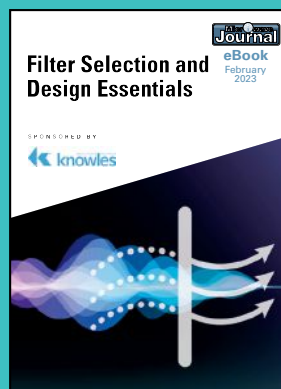
**Who Has the Highest Power GaN Power
Amplifiers?**



Register to attend at mwjournal.com/webinars

FEATURED  **eBooks**

mwjournal.com/ebooks



Advertiser	Page No.	Advertiser	Page No.	Advertiser	Page No.
3H Communication Systems	55	Exceed Microwave	87	Passive Plus	COV 2
Agile Microwave Technology Inc.....	54	Exodus Advanced Communications, Corp.....	57	Pasternack	8
AmpliTech Inc.	35	Fairview Microwave	72, 73	Pletronics, Inc.	64
AnaPico AG	24	Fujian Mlcable Electronic Technology Group Co., Ltd.....	67, 75	Quantic PMI (Planar Monolithics)	23
AR RF/Microwave Instrumentation.....	63	GGB Industries, Inc.	3	Reactel, Incorporated.....	39
Artech House	94	Herotek, Inc.	74	RF-Lambda.....	9, 25, 59, 77
AT Microwave	33	HYPERLABS INC.	49	RFMW	13, 47, 65, 83
Avtech Electrosystems	93	IEEE MTT-S International Microwave Symposium 2023	79, 85	Richardson Electronics.....	31
B&Z Technologies, LLC	11	iNRCORE.....	69	RLC Electronics, Inc.	21
Berkeley Nucleonics Corp.	24	Knowles Precision Devices	47	Rosenberger	27
Cernex, Inc.	76	KR Electronics, Inc.....	93	Safran Electronics & Defense	38
Charter Engineering, Inc.....	82	KVG Quartz Crystal Technology GmbH	87	Smiths Interconnect	70
Ciao Wireless, Inc.....	36	LadyBug Technologies LLC.....	28	Special Hermetic Products, Inc.	88
Coilcraft.....	58	M Wave Design Corporation.....	89	Spectrum Control (formerly APITech)	7
COMSOL, Inc.....	15	Marki Microwave, Inc.....	61	Spectrum Instrumentation GmbH.....	46
Connectronics Inc.	93	Microwave Components Inc.	78	Swift Bridge Technologies	32
CPI (Communications & Power Industries).....	34	<i>Microwave Journal</i>	86, 92, 95	Synergy Microwave Corporation.....	45, 71
Dalian Dalicap Co., Ltd.....	43	Millimeter Wave Products Inc.....	53	Taitien Electronics Co., LTD.....	66
dB Control Corp.	82	Mini-Circuits	4-5, 16, 40, 97	Tecdia, Inc.	52
EDI CON Online 2023.....	COV 3	MiniRF Inc.....	83	Weinschel Associates.....	26
Empower RF Systems, Inc.	42	Norden Millimeter Inc.	91	Wenteq Microwave Corporation.....	93
ERAVANT	18-19	Nuvotronics	65	Werlatone, Inc.....	COV 4
ERZIA Technologies S.L.	51	Nxbeam	29	Z-Communications, Inc.....	60
EuMW 2023	81	OML Inc.....	6		

Sales Representatives



Eastern and Central Time Zones

Michael Hallman
Associate Publisher
(NJ, Mid-Atlantic, Southeast, Midwest, TX)
Tel: (301) 371-8830
Cell: (781) 363-0338
mhallman@mwjournal.com

Shannon Alo-Mendoza
Northeastern Reg. Sales Mgr.
(New England, New York, Eastern Canada)
Tel: (781) 619-1942
Cell: (978) 501-9116
salomendoza@horizonhouse.com

Submitting ad material?

Visit: www.adshuttle.com/mwj
(866) 774-5784
outside the U.S. call +1-414-566-6940

Pacific and Mountain Time Zones

Brian Landy
Western Reg. Sales Mgr.
(CA, AZ, OR, WA, ID, NV, UT, NM, CO, WY, MT, ND, SD, NE & Western Canada)
Tel: (831) 426-4143
Cell: (831) 713-9085
blandy@mwjournal.com

Ed Kiessling
(781) 619-1963
ekiessling@mwjournal.com

International Sales

Richard Vaughan
Tel: +44 207 596 8742
rvaughan@horizonhouse.co.uk

Germany, Austria, and Switzerland (German-speaking)

WMS.Werbe- und Media Service
Brigitte Beranek
Tel: +49 7125 407 31 18
bberanek@horizonhouse.com

France

Gaston Trouboulsi
Tel: +44 207 596 8742
gtrouboulsi@horizonhouse.com

Korea

Young-Seoh Chinn
JES MEDIA, INC.
Tel: +82 2 481-3411
corres1@jesmedia.com

China

Shanghai
Linda Li
ACT International
Tel: +86 136 7154 0807
lindal@actintl.com.hk

Hatter Yao
ACT International
Tel: +86 139 1771 3422
hattery@actintl.com.hk

Wuhan

Phoebe Yin
ACT International
Tel: +86 134 7707 0600
phoebey@actintl.com.hk

Shenzhen

Floyd Chun
ACT International
Tel: +86 137 2429 8335
floydchun@actintl.com.hk

Beijing

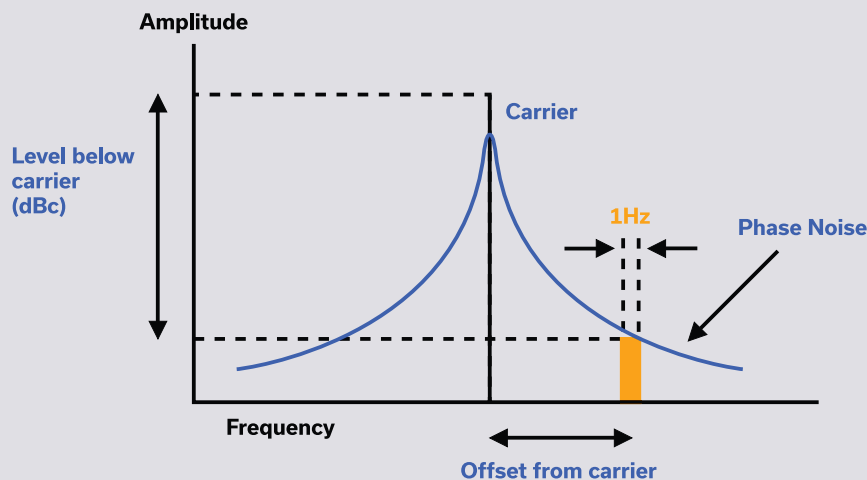
Cecily Bian
ACT International
Tel: +86 135 5262 1310
cecilyb@actintl.com.hk

Hong Kong, Taiwan, Singapore, Malaysia

Floyd Chun
ACT International
Tel: +852 28386298
floydchun@actintl.com.hk

Japan

Katsuhiro Ishii
Ace Media Service Inc.
Tel: +81 3 5691 3335
amskatsu@dream.com



INDUSTRY-LEADING PERFORMANCE

Low Phase Noise Amplifiers

For Sensitive Transceiver Systems

- Additive phase noise as low as -173 dBc/Hz @ 10 kHz Offset
- Ideal for radar, test instrumentation and more
- Wide selection in stock for the most demanding requirements
- State-of-the-art measurement capability in house



[View phase noise specs](#)



 **Mini-Circuits®**

FAB\$ and LAB\$

Guerrilla RF: Making Better Networks™



Celebrating its tenth anniversary, Guerrilla RF was founded by North Carolina State University graduate Ryan Pratt. Pratt, with a degree in electrical engineering, had previous RF component experience in the North Carolina area working his way up the RFIC design and engineering management ladder at RFMD before founding and becoming director of the Skyworks design center in Greensboro, NC. Following a change in leadership at Skyworks in 2013, Pratt founded Guerrilla RF that April. Shortly thereafter, he established an office in the Nussbaum Center for Entrepreneurship, a small business incubator catering to startups in Greensboro, NC. The entrepreneurial spirit runs deep in the Pratt family as Bill Pratt, Ryan's father, was one of the co-founders of RFMD.

From these beginnings, Guerrilla RF has grown from the first hire in early 2014 to more than 70 employees worldwide. As the company has grown, so have its accomplishments. 2014 saw the first GaAs pHEMT LNA shipment, which was followed by power LNAs, driver amplifiers, gain blocks, RF switches, attenuators, mixer cores, power detectors and power amplifiers. From the early days of GaAs, Guerrilla RF has diversified its technology portfolio to include InGaP and SOI. The company has used this expanding product and process portfolio to surpass 150 million devices shipped in mid-2022. After supporting this growth with several private funding rounds, the company went public in October 2021. For the year ending December 2022, Guerrilla RF reported record revenues of \$11.6 million, a 10.7 percent increase year-over-year.

As Guerrilla RF's product and technology portfolios, shipments, revenues and staff have grown, they are realizing the need to expand their physical footprint. In February 2023, the company moved into a new headquarters in Greensboro that provides 55,000 square feet total with 11,000 square feet of lab space. This is a substantial upgrade from

the 10,800 square feet of office and lab space they utilized for more than nine years previously.

In an ecosystem that loves a certain amount of vagueness and ambiguity in company names, like Qorvo, Skyworks, Broadcom and Avago, "Guerrilla RF" provides a clarity of purpose. The name reflects a strategy of targeting bigger competitors in markets and applications where those companies are not focused and resourced correctly. Guerrilla RF views these areas as underserved markets and they believe addressing these areas with a portfolio of the right products will create significant business opportunities and help differentiate the company from its competitors.

While some of their broadband gain blocks operate as high as 12 GHz, most of Guerrilla RF's broad mix of control components, amplifiers, mixers and detectors are designed to operate in frequency ranges at or below 6 GHz. These products are capturing market share in various 4G/5G small cell and 5G massive MIMO antenna applications. Automotive applications are a key target area, with Guerrilla RF's products being designed into GPS/GNSS front-end applications, SDARs front-ends and V2X compensators. The company's parts are also well-represented in the growing repeater/DAS market.

Guerrilla RF made the Inc. 500 list of fastest-growing private companies twice before it went public and its trajectory of product development, revenues and expansion bode well for continuing this growth now that the company is public. The rapid growth of any company presents challenges, but Guerrilla RF looks well-positioned to address these challenges. Ryan Pratt and Guerrilla RF's senior management are acutely aware of maintaining a work-life balance and they are proud of the fact that their parking lots are mostly empty by 5:15 PM as they guide the company along the next phase of growth.

www.guerrilla-rf.com

Mark Your Calendar!



Every Wednesday in October 2023
4 Focused Tracks With
Free Seminars

Oct. 4

**Signal
Integrity/Power
Integrity**

Oct. 11

**5G/
Wi-Fi/
IoT**

Oct. 18

**PCB/
Interconnect/
EMC-EMI**

Oct. 25

**Radar/
Automotive/
SATCOM**

EARN IEEE CEU/PDH CREDITS!

Platinum Sponsors:



EDICONONLINE.COM



DIGITAL RF POWER METERS

Optimal Accuracy ✦ 40 dB Dynamic Range ✦ No Calibration Required

Simultaneously Monitor: Forward Power, Reverse Power, Load VSWR, & Temperature

ACCURACY

- Multi-Octave Solutions provide accuracy within $\pm 5\%$ of a Customer Lab Standard ($\pm 2\%$ Typical).

CALIBRATION

- No On-Site Calibration Required.
- Calibration Routine completed internally to each Power Sensor.
- Traceable to National Institute of Standards & Technology (NIST).

ALARMS & RELAYS

- Alarm Thresholds of Forward & Reverse Power.
- Full VSWR Monitoring/Alarm Capability.
- Full Temperature Monitoring/Alarm Capability.
- Six General Purpose Inputs & 2 Form-C Relays to External Devices

FIRMWARE

- Windows Application includes an ergonomic tab-based access system for easy setup and operation of the Power Meter.
- Multi-Window Display for access to up to five Meters on screen.
- VSWR Indication & Reflected Power on main Power Sensor display.
- MIB File available for use with SNMP software.
- LabVIEW Driver Available.

