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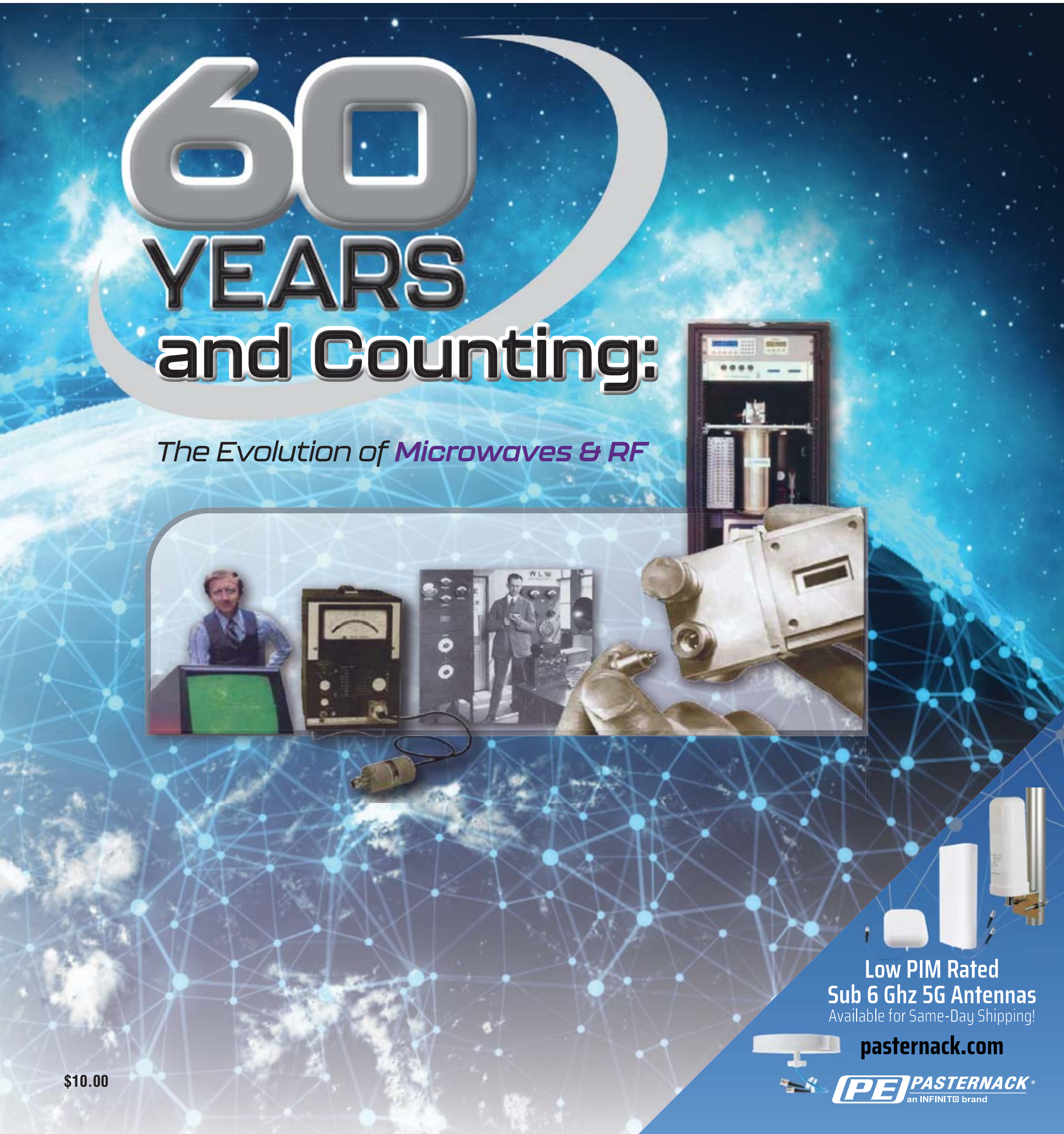


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60 YEARS

## FEATURES



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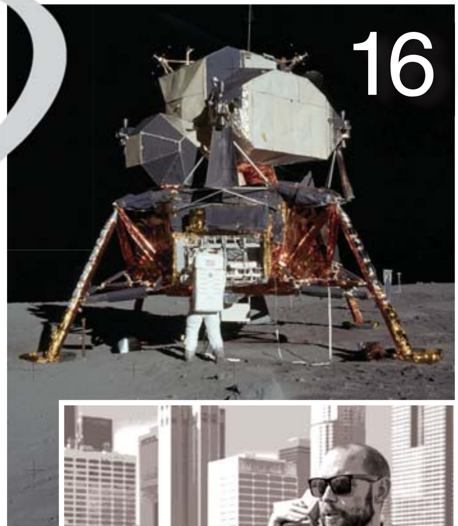


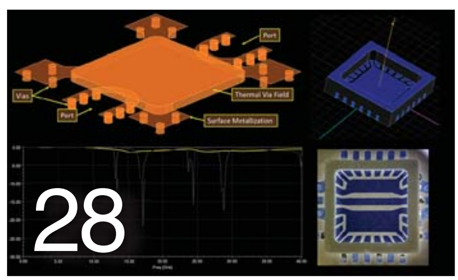




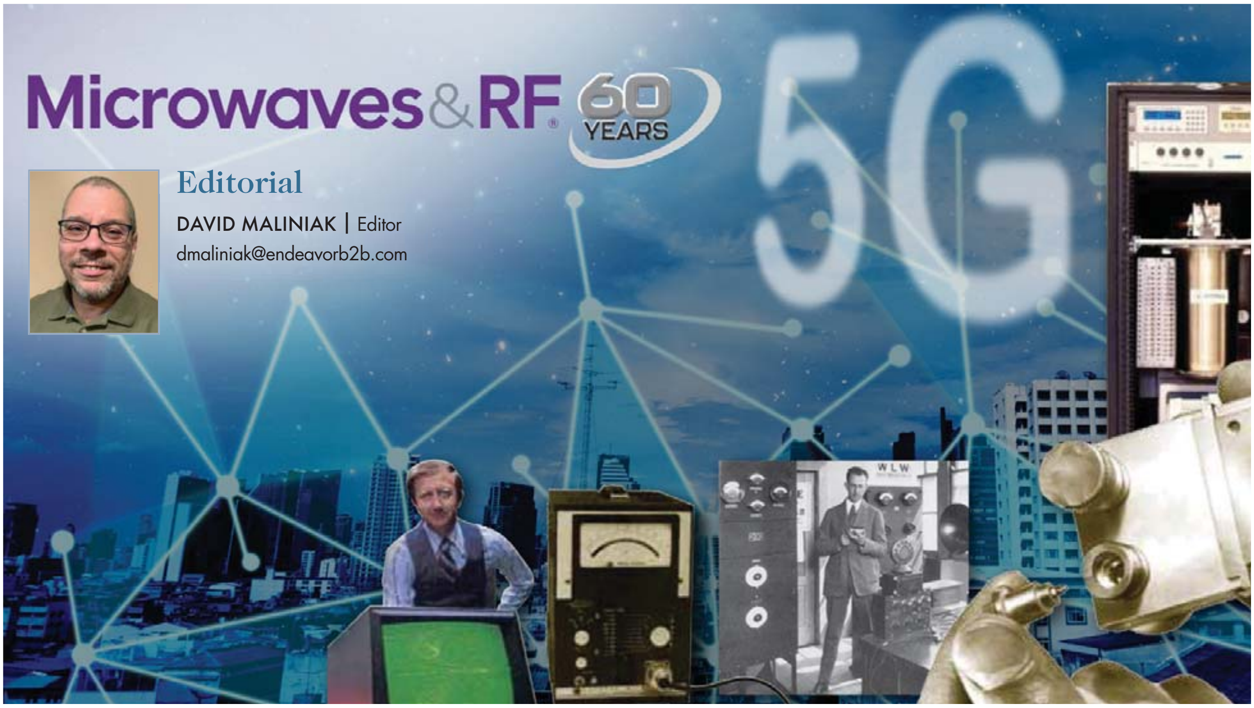


Microwaves & RF 60 YEARS

Editorial

DAVID MALINIAK | Editor
dmaliniak@endeavorb2b.com

# Looking Back on Six Decades of Innovation

**From the earliest radars to today's ever-advancing IoT systems, microwaves and RF technology has had and continues to play an essential role in all avenues of communications.**

With this issue, we mark the 60th anniversary of *Microwaves & RF's* publication as a magazine/website dedicated to serving high-frequency electronic design engineers with the information and insight they've needed to get their jobs done. In doing so, we've been what one might call an "eye in the sky," keeping track of the microwave/RF industry's progress over these six decades.

And what a journey it's been, full of companies, characters, and continuous innovation, from the vacuum-tube-based radar systems that helped win wars to the mmWave 5G cellular technology that keeps our world connected today. RF and microwave technologies have been instrumental in many seminal events and developments over these 60 years, enhancing and enriching our lives in myriad ways.

None of our accomplishments in space travel and exploration would have been possible without them, from the early years of satellites to the rovers now drilling holes in Martian rocks. We're on the verge of "smart everything," with wireless IoT/IIoT technology pervading our homes, offices, schools, factories, hospitals, and retail businesses.

Our vehicles are smarter and safer thanks to advanced driver-assistance systems (ADAS) that rely on, among other things, radar, Global Positioning Systems (GPSs), and all manner of wireless sensors. And how could we have possibly endured the pandemic without our smartphones, tablets, and laptops wirelessly streaming music, movies, and games via Bluetooth and Wi-Fi, probably when we should have been working from home?

It's hard to even know where to start on the contributions of the RF and microwave industry to national security and our safety from foreign and domestic threats. From satellite and drone surveillance to highly sophisticated weapons and targeting systems, the realm of electronic warfare will take us into the future, saving many lives of our men and women in uniform along the way.

I'm only the latest of the editors who've had the privilege of guiding *Microwaves & RF* through its 60 years of existence, and I stand on the shoulders of those who came before me. Most notable among them is Jack Browne, who joined the magazine in 1981 *(p. 21)* and continues in his role as a contributing editor to this day. Jack put together the 12-page special section of industry timelines that forms the core of this anniversary celebration, and who better to do so? After all, he's been along for two-thirds of the ride; his long hours of work on the timelines were a labor of love for the industry he's chronicled for 40 years. We're grateful for his contribution and long service.

As for myself, I'm honored to be on board for this milestone. What began as a print magazine mailed to readers is now a multimedia enterprise that spans an associated website, digital magazines, e-books, newsletters, videos, webinars, social media channels, and lots of other resources that we hope are helpful to you. We're looking forward to getting started on the next 60 years and improving our service to the industry. ■

# Planar Monolithics Industries

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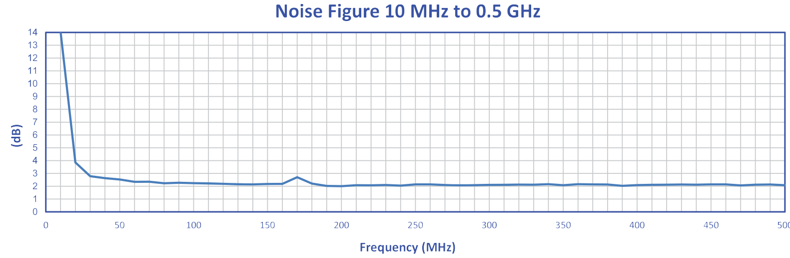
PLNA-30-10M20-292FF

PEAFS3-14-10M22G-292FF

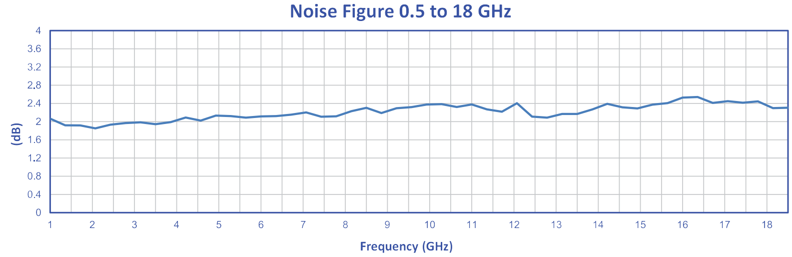
LNA-0R518G-45-10DBM-SFF

| PMI Model No. | Frequency Range (GHz) | Gain (dB) | Gain Flatness (dB) | Noise Figure (dB) | OP1dB (dBm) | Configuration Size (Inches) Connectors |
|---|---|---|---|---|---|---|
| PEAFS3-14-10M22G-292FF | 0.01 - 22 | 14 | ±0.8 | 2.5 | +14 (0.01 - 18 GHz) +13 (18 - 22 GHz) | 0.53" x 0.70" x 0.26" 2.92mm (F) Removable |
| PLNA-30-10M20-292FF | 0.01 - 20 | 28 | ±2.5 | 2.5 | +14 (0.01 - 18 GHz) +13 (18 - 20 GHz) | 0.53" x 0.70" x 0.26" 2.92mm (F) Removable |
| LNA-0R518G-45-10DBM-SFF | 0.5 - 18 | 45 | ±2.0 | 2.95 | +10 | 0.90" x 1.67" x 0.36" SMA (F) Removable |

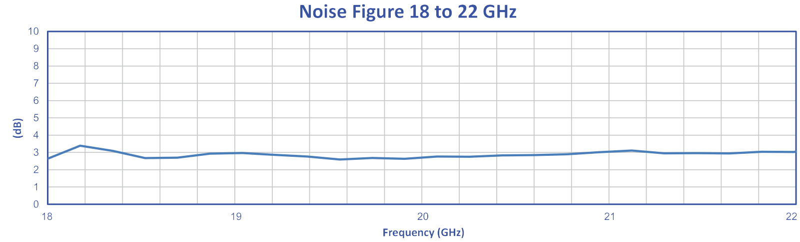
Noise Figure 10 MHz to 0.5 GHz




Noise Figure 0.5 to 18 GHz




Noise Figure 18 to 22 GHz




*Typical data for PMI Model PEAFS3-14-10M22G-292FF*

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## DE-RISKING THE TECHNOLOGY PATH TO CMOSS

CMOSS is increasingly on the radar of mil-aero bodies seeking to deploy tactical comms in vehicles that meet SWaP specs and ensure a smooth path to the architecture. Challenges exist, though, and this article lays out a blueprint to de-risk that path.

***www.mwrf.com/21178927***

## THE CRITICAL NATURE OF QUALITY COAX FOR FIELD TESTING

Coaxial cables for RF field-test applications must meet stringent requirements for environmental and mechanical ruggedness. Here's a look at how the construction and quality of coax can make or break the efficiency of test for cellular providers.

***www.mwrf.com/21178156***


## THE EVACUATED MINIATURIZED CRYSTAL OSCILLATOR: A STEP UP FOR SPACEFLIGHT APPS

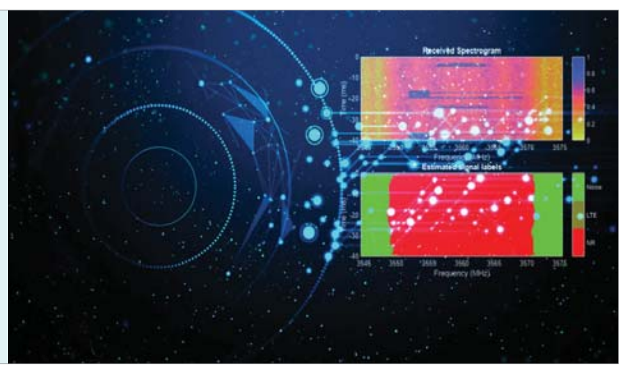
The EMXO is smaller than other components, uses less power, and offers other advantages for designers trying to meet the tough demands of space systems.

***www.mwrf.com/21173396***

## SPECTRUM SENSING USING DEEP-LEARNING TECHNIQUES

This edition of Algorithms to Antennas investigates spectrum sensing that leverages deep-learning techniques to identify 5G NR and LTE signals.

***www.mwrf.com/21178938***



# News

## Field Instrument for O-RAN Deployment Gets 5G Cell Sites Up and Running

**Viavi's latest field instrument feeds the O-RAN revolution in 5G cell sites by getting them operational faster and at lower installed cost.**


(Credit Viavi Solutions)

### The Overview

Viavi Solutions's OneAdvisor-800 is an all-in-one cellular site test tool with comprehensive capabilities for cell-site deployment, including:

- Fiber inspection and characterization
- Cable and antenna analysis
- Open RAN (O-RAN) radio verification (when upgraded with the O-DU Emulation application).

### Who Needs It and Why?

Service providers and equipment manufacturers worldwide are adopting open radio-access networks to reduce infrastructure costs and lower the barrier to entry for new product innovation. In line with these benefits, O-RAN also enables carriers to thoroughly validate the tower installation very early in the process, thereby reducing installation problems and accelerating deployments. Viavi's OneAdvisor-800 cell site test tool brings the company's savvy in O-RAN specifications development and wireless lab validation platforms to bear on the field requirements for getting 5G sites up and running.

### Under the Hood

OneAdvisor-800 is a single, modular instrument that helps cell-site technicians test fiber, radio frequency (RF), and Common Public Radio Interface (CPRI), eliminating the need for multiple independent tools. The addition of the Open Distributed Unit (O-DU) Emulation application further streamlines site verification and guards against future site visits by technicians by enabling functional testing of the Open Radio Unit (O-RU) upon installation, rather than waiting until the O-DU is in place. The technician's work is simplified by guided workflows, with Job Manager programming the service provider's test criteria, and automatically uploading results to the StrataSync cloud.

With its modular design philosophy, the OneAdvisor-800 is, in a sense, future-proofed. The addition of O-RAN radio verification through the O-DU Emulation application is an indication of Viavi's commitment to support the entire network lifecycle.

Viavi's comprehensive test platform for lab validation, field deployment, and service assurance of O-RAN networks is able to validate that all interfaces are working correctly—including RF, O-DU, O-RU, signaling, transport, timing, and synchronization—and equipment is performing to specifications even under load and stress, from the lab to the field. Viavi also helps network operators ensure interoperability—a key concern in a multi-vendor-based O-RAN environment. ■

## Design Kit Provides Quick Access to Crystal Resonators

**IN A BID TO FACILITATE** design projects involving crystal resonators, Raltron now offers a Crystal Resonator Engineering Design Kit comprising more than 60 combinations of frequencies, load capacitances, and package sizes that are recommended for use with many of the popular ICs on the market.

The crystal resonator design kit includes frequencies from 8 to 50 MHz in ceramic package sizes from 5032 to 1210, and 32.768 kHz in 3215 to 1210 size packages. A printed card behind each sample pocket allows the user to connect to a special website providing the Raltron part number, part description, full specs, environmental data, an RFQ form, and a connection to distributors who carry the item in inventory. Users can also request additional samples or parameter modifications to existing kit items to obtain an optimum specification for a given design.

Raltron's crystal resonator design kit is available through authorized stocking distributors. For access to product series datasheets and the kit utilization video, visit *https://www.raltron.com/2021/08/raltron-crystal-design-kit/*. ■


(Credit Raltron)

THE NOW

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TRANSCOM

# Toward Efficient and Reliable **Microwave Power Amplifier Devices and Subsystems**

*Taiwan's Transcom has steadily marched toward GaAs/GaN-based RF power amplifier devices and subsystems that deliver higher power, lower noise, excellent linearity, and high reliability in microwave and mmWave applications.*


**TC5287C & TC5285C 26.5-31.5GHz 3W High Linearity GaAs PA MMICs**

**THE HEART AND SOUL** of wireless systems for applications including radar, satellite communication, and 5G/mmWave infrastructure is the power semiconductors and amplifiers that generate their gain-stage and final output-stage RF power. Such devices and subsystems must deliver high power with low noise, high efficiency, and good linearity; they also must be highly reliable as they are often difficult or even impossible to change out after field deployment (in low-earth-orbit satellite scenarios, for example).

In 1998, Chian S. Chang leveraged his technical background in high-quality power devices with organizations such as Celeritek and Avantek/HP by founding a new company. Since then, Taiwan's **Transcom, Inc.** has been among the leaders in gallium arsenide/gallium nitride (GaAs/GaN) RF power-amplifier subsystems, monolithic-microwave ICs (MMICs), and field-effect transistors (FETs). Other aspects of the company's product lines include custom and low-noise amplifiers, diodes, hybrid ICs, and microwave-IC modules (MICs).

Applications for Transcom's GaAs/GaN devices and subsystems are many across a range of categories. In radar systems, their products can be found as amplifier/SSPAs, synthesizers, and MMICs in radar transmitters. Radar receivers benefit from Transcom low-noise amplifiers, MMICs, and FETs.

When it comes to 5G/mmWave infrastructure and small-cell/fixed-wireless-access applications, Transcom's power-amplifier MMICs serve important functions in small cells, whether deployed by users/partners or telecom operators; those in cellular base stations; or those in optical-fiber or mmWave applications.

Transcom has persevered throughout its history to better the quality and reliability of its products. It has consistently driven its SSPA products toward higher power-output levels, higher efficiency, and lower size/weight. Similarly, the company's MMICs and FETs have moved up in frequency to the Ka-band and higher with improved efficiency and linearity.

The company gains its technology edge by virtue of its in-house GaAs PHEMT and GaN HEMT fabrication processes, which enhances its design capabilities and shortens time-to-market for its microwave and communication MMICs/SSPAs products. Transcom now operates a 36,500-square foot manufacturing facility, with an additional 47,000 square feet due to come online in the first quarter of 2022. Its 5000-square foot Class 100 clean room currently generates 15,000 wafers annually. With the additional manufacturing space, Transcom plans to continue its R&D into GaAs/GaN high-power and high-frequency broadband semiconductor devices and subsystems.

To illustrate the technical sophistication of Transcom's products, its **TC5287C, a 3W, three-stage power amplifier MMIC,** operates from 26.5 to 31.5 GHz in applications such as 5G New Radio links, VSAT terminals, SATCOM, and point-to-point radio. The amplifier delivers a typical 23 dB of gain and +34 dBm of saturation output power (PSAT). The MMIC is fabricated on Transcom's GaAs PHEMT process, which features full passivation for increased performance and reliability.

***www.transcominc.com.tw/index.php***

# **mmWave 5G PAAM,** Made in Bulk CMOS, Sports 300+ Antennas for Infrastructure Buildout


*(Credit Movandi)*

### The Overview

Movandi's phased-array antenna module (PAAM) design, which comprises over 300 antennas, leverages the scale and cost efficiency of TSMC's bulk CMOS technology to deliver breakthrough performance. Movandi's phased-array antenna module delivers a suitable combination of output power, cost, antenna count, and energy efficiency for mmWave infrastructure applications.

### Who Needs It and Why?

For those enmeshed in the buildout of mmWave 5G infrastructure, this demonstration by Movandi of an advanced PAAM design based on TSMC's bulk CMOS process is a watershed moment. CMOS technology provides industry-leading cost, effective isotropic radiated power (EIRP), and dc efficiency when compared to other options. Movandi's CMOS-based PAAM has the potential to blend a low price point, moderate output power per port, optimal antenna count, and excellent thermal density into an overall solution for end-product design.

### Under the Hood

The PAAM incorporates Movandi's production-shipping beamformer, up/down converter, and synthesizer chips. Deep application RAMs on all Movandi chipsets allow programmable schedules and a large beam-book for dynamic control and fast beamsteering. A symbol-level PAAM controller enables accurate time-division duplexing (TDD), AGC, and beamforming, as well as power-saving modes that include symbol-level power save and tapering.

The Movandi PAAM was developed to support a custom O-RAN radio unit product and is capable of >59 dBm EIRP per beam. The PAAM is configurable in several modes of operation including 2T2R, 4T4R, and 8T8R. The PAAM achieves this EIRP while maintaining better than 4% error-vector magnitude (EVM). ■

# **20-dB Single-Step Programmable Attenuator** Serves in Scientific Instruments

### The Overview

BroadWave Technologies's Model 651-038-020, a 20-dB single-step programmable attenuator, is designed for use in scientific instruments.

### Under the Hood

The voltage-controlled device covers a frequency range from dc to 2.5 GHz. Attenuation range is 0 to 20 dB in a 20-dB step with ±0.6-dB attenuation accuracy. Insertion loss is 0.6 dB maximum while VSWR is 1.40:1 maximum. Input power is 1 W average with supply voltage of +15 V dc @ 30 mA nominal.

*(Credit BroadWave Technologies)*

The RF connectors are SMA female, and the control solder terminal features a feed-thru capacitor to prevent leakage. Other attenuation values and RF connector types are available. ■

# K-band Passive Components Serve Space Applications

**ISOLATORS, CIRCULATORS,** iso-adapters, and loads are born of an extensive product line and are specifically engineered to reduce cost and NRE charges for users.

## The Overview

Smiths Interconnect's broad range of K-band passive components for satellite communication payloads in GEO/MEO and LEO orbits includes coaxial and WR51 isolators, circulators, and iso-adapters; waveguide loads, and microstrip isolators.

## Who Needs It and Why?

Building on over 30 years of experience and flight heritage, the company's many potential design variants, all of which are specifically engineered to meet the needs of spaceflight applications, enables it to exploit a very large product portfolio to minimize non-recurring costs for users. These highly compact and ruggedized K-band passive components are rigorously qualified for spacecraft use in the company's state-of-the-art test and qualification laboratory in Dundee, Scotland. Qualification comprises sine and random vibration, mechanical shock, and, where appropriate, RF power TVAC, average power and multipaction, and critical power testing. Summary and qualification data reports are available to prospective customers.

## Under the Hood

The company's K-band coaxial and WR51 isolators, circulators and iso-adapters, waveguide loads and microstrip isolators are broadband devices and, as such, require fewer part options to address the allocated frequency band. They are temperature-stable and multipaction-free.

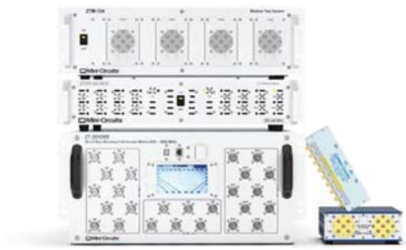
They are provided with a standard clear passivation coating but can be supplied with a low-emissivity black paint finish if desired. Their design is optimized for reliability and minimizes cost and application risks. Mechanical variants (circulation, flange detail, and more) are available on request. ■

DC TO 65 GHZ

# RF & Microwave Test Solutions

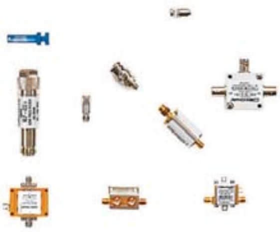
Get More Out of Your Test Setup

**Software Controlled Building Blocks and RF Interface Units**



**Custom Test Systems**

**Test Accessories**



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# Microwaves & RF®

*A look back at the people, products, and technologies that have impacted our industry.*

*MicroWaves* magazine was launched in 1961 to serve a growing number of electronic engineers working with high-frequency electromagnetic (EM) waves. Engineers were working at firms focused on expanding microwave technologies applied during World War II (WWII), including radar and electronic-warfare (EW) systems. Radars were powered by vacuum-based electronic devices such as magnetrons, klystrons, and traveling wave tubes (TWTs), better known as "tubes."

Many companies contributed to the growth of RF/microwave technology in the 1960s, seeking to find uses other than radar for the technology after the war. Among those companies were firms largely devoted to defense-related markets, including Raytheon Co. (Waltham, MA), the Microwave Laboratory of General Electric Co. (Palo Alto, CA), TRW, Inc. (Los Angeles, CA), Northrop Grumman (which would acquire TRW), and the Electron Devices Division (EDD) of Hughes Aircraft Co. Raytheon's Percy Spenser might have been better known for his invention of the microwave oven (in 1947), introduced to the general public under the Amana brand name. Spenser noticed the effects of a magnetron's EM radiation by a melted candy bar in his pocket.

Beyond military electronics, space became an important frontier for RF/microwave engineering efforts, with so much investment from different government organizations fueling "the space race" between the U.S. and the Soviet Union. Companies with missile guidance legacies such as TRW and Northrop Grumman were candidates for space missions such as NASA's Apollo Program to land a man on the moon. For example, TRW built six Tracking and Data Relay System satellites (TDRSS) for NASA while Northrop Grumman built the lunar landing module for the Apollo Program. The R&D needed for communications and navigation systems for space exploration continued to push RF/microwave engineering forward, into smaller, lighter components (a trend that continues 60 years later). The same companies also integrated RF/microwave technology into the rapidly growing number of satellites being used for surveillance and communications.

One of the largest early commercial applications of microwave technology was in AT&T's nationwide communications network based on microwave radio relays. Built in the 1950s and used in the 1960s, the network was a precursor of modern wireless cellular networks. Rather than running cables from tower to tower, it transferred telephone signals across the country from tower to tower with line-of-sight (LOS) microwave transmissions. mw

## 1960

**Founded in 1957** by Harold Isaacson and later managed by his wife Florence and son Roby, Antenna and Radome Research Associates (ARRA) has been a leading designer and developer of RF/microwave coaxial and waveguide components and an early supplier of waveguide components. With over 2,000 designs, the family-owned business (Bay Shore, NY) is perhaps best known for its attenuators, although it also designs and produces adapters, couplers, power dividers/combiners, switches, and terminations.

*(Photo courtesy of ARRA Inc.)*


## 1966

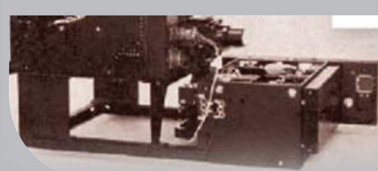
**Rohde & Schwarz** installs the first computer within the family-owned business, a computer with 4 kB of core memory. That computer, used for payroll processing, would represent a precursor to the great amount of design and development on microprocessor-controlled and automated test instruments from audio through microwave frequencies.

## 1965

**An important milestone** in the industry's testing capabilities occurred with the introduction of the model 310 impedance meter, a forerunner to the RF/microwave VNA, by Wiltron Co. The VNA enabled detection of signal amplitude and phase, allowing measurement of scattering (S) parameters to determine device impedances at microwave frequencies. Hewlett-Packard would introduce its own VNA in 1966.

## 1966

**Millimeter-wave (mmWave)** signals were not common, but they were used by the military even 60 years ago. A radar system developed by North American Aviation (Columbus, OH) used short pulses at pulse widths from 4 to 250 ns and a pulse-repetition frequency (PRF) of 1 kHz. The system was noteworthy for its portability and its capability of generating 10-kW pulsed signals at mmWave frequencies. (from Jan 1966 issue).



## 1967

**Phased-array antenna** technology was generating a great deal of interest within the RF/microwave industry due to its capability to shift the direction of an antenna beam by voltage tuning of phase, without physically moving the antenna.

60 YEARS

*Sponsored by:*

US Universal Switching Corporation

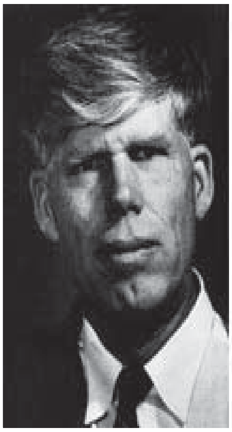
**Automating RF connections** seemed absurd at the time, but **Universal Switching's** roots began in 1968 with a burst of innovation as "Matrix Systems Corp" by introducing a modular coax switching line, and a 100MHz compact 8x8 matrix in a 4" cube. The founders of Universal Switching departed MSC in 1992 to introduce new technology (USC later acquired MSC in 2007) and now offers automated switch solutions to 50GHz.

**uswi.com**

## 1960

**RHG Electronics Laboratory** was founded in Farmingdale, NY by Arnold Rubin, Ron Hirsch, and Robert Gruber, lending the first letter of each last name for the company name. The company, a leading supplying of RF/microwave mixers, video amplifiers, and other components for military and aerospace systems, would move to Deer Park, NY a decade later and eventually be acquired by M/A-COM.

*(Courtesy of WorldRadioHistory.com)*



## 1962

**The Varian brothers,** Sigurd and Russell, celebrated the 25th anniversary of their company, Varian Associates (Palo Alto, CA) in 1962. They were responsible for key vacuum electronics sources of microwave energy including the klystron.

## 1963

**Another two-partner** Bay-area company that would play a major role in the growth of the RF/microwave industry, Hewlett-Packard Co. (Palo Alto, CA), introduced the first industry's frequency-synthesized microwave signal source. Bill Hewlett and Dave Packard started the company in 1939. The firm would contribute many significant test instruments, not only for microwaves but audio, analog, and digital electronics. For its 25th anniversary in 1964, the company launched the HP 5060A cesium atomic clock for precision time keeping and synchronization of instruments and systems.

*(Courtesy of Hewlett-Packard Co.)*

## 1963

**Watkins-Johnson Co.** (Palo Alto, CA) was one of several San Francisco Bay-area companies driven by U.S. DoD defense spending and the need for advanced microwave technology for defense-based systems. Started in 1957 with a goal to advance microwave EM technology, the company's founders were Dean Watkins (left), who had been a microwave engineering professor at Stanford University, and Dick Johnson (right), who had led the microwave laboratory at Hughes Aircraft Co. As part of its rapid early growth during the 1960s, the company acquired backward-wave-oscillator (BWO) developer Stewart Engineering Co. (Santa Cruz, CA) in 1963 and surveillance/reconnaissance systems supplier Communication Electronics, Inc. (Rockland, MD) in 1967. Watkins-Johnson Co. became well known for receiving systems such as the model WJ-566.

## 1962

**One of the early RF/microwave component companies,** Microwave Associates, was founded in 1950 in Boston, MA. The company formed to design and manufacture coaxial and waveguide components and assemblies, with one of the first products a magnetron for microwave radar systems. Microwave Associates would grow into a multinational public company later known as M/A-COM with its first IPO in 1957.

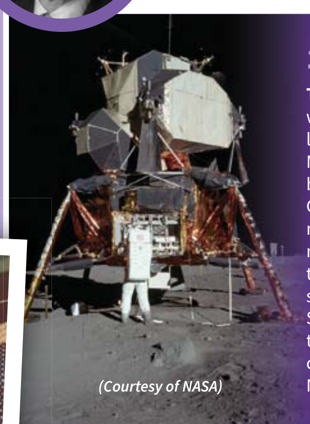
*(Courtesy of www.Macom.com)*

The technology was put on display in Florida with the AN/FPS-85 phased-array radar, the first phased-array radar used for space surveillance.

*(Courtesy of DoD)*

## 1968

**Harvey Kaylie founded Mini-Circuits** in Brooklyn, NY, with the vision of providing high-performance, high-quality RF/microwave components for the lowest cost possible. Kaylie, a graduate of City College of New York (CCNY) who was aided by his wife Gloria and their two daughters in those early years, aggressively grew the company from a handful of basic RF components such as mixers and amplifiers to an expansive catalog of active and passive components that embraced the most practical technologies, including GaAs MMICs and LTCC filters. Kaylie passed away in mid-2018, leaving behind a company that remains a world leader in RF/microwave products.



*(Courtesy of NASA)*

## 1969

**The decade ended** with the successful landing of the Lunar Module spacecraft built by Northrop Grumman on the moon. This Apollo mission and many of the previous Apollo spacecraft relied on S-band antennas and transceiver circuitry for communications with NASA teams.

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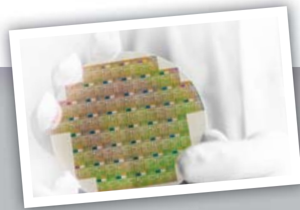
*A look back at the people, products, and technologies that have impacted our industry.*

## 1970

**AT&T's "Long Lines"** radio links represented the state of the art in voice and data communications, replacing long runs of metal cables with tower-mounted directional horn antennas. Long replaced by cellular networks, Long Lines towers supported line-of-sight (LOS) microwave links in a zig-zag configuration across the country.

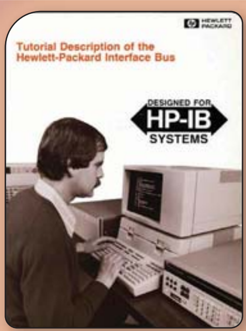
*(Image from 99% Invisible, www.99percentinvisible.org)*



## 1970

**Gallium arsenide (GaAs)** was gaining popularity in RF/microwave applications as it became more practical with the deposition of larger semiconductor wafers. Plessey Research (Towcester, Caswell, England) introduced a commercial discrete GaAs MESFET, its model GAT-1, in 1970, and would unveil its first GaAs MMIC in 1974. RCA Laboratories (Princeton, NJ) also contributed strongly to the development of GaAs semiconductors during the decade. *(Image courtesy of Wafer World, Inc.)*

*(Photo courtesy of Genalog)*




## 1975

**Test equipment** became "computerized" with the introduction of Hewlett-Packard's Interface Bus (HP-IB) interface system to simplify the connection of computers to test instruments. The 8-bit digital parallel communications bus, which became generally known as the General-Purpose Interface Bus (GPIB), served as a starting point for many instrumentation interfaces and functioned as a peripheral bus for early microcomputers. The bus was adopted as the IEEE 488 standard in 1975.

## 1974

**As operating frequencies rose,** coaxial connectors were designed with smaller dimensions for higher frequencies. An early version of a coaxial connector for mmWave frequencies, the MPC3 connector, was introduced by Maury Microwave Co. for use to 26 GHz. The 3.5-mm-diameter connector would begin a trend in the development of smaller coaxial connectors for higher frequencies, as the industry would extend coaxial test equipment to the mmWave range. For example, 10 years later, Wiltron Co. (which would become part of Anritsu) would introduce the 2.92-mm "K" connector for use to 40 GHz.

## 1973

**The U.S. Naval Electronics Laboratory Center (NELC)** in San Diego, CA performed innovative computer modeling and simulations to develop a frequency-modulated, continuous-wave (FMCW) radar with 200 W transmit power from 2.8 to 3.0 GHz. Tuned by a microwave YIG oscillator, the system was alleged to have the capability to detect a house fly at an altitude of 10,000 ft. The system's two 10-ft.-diameter parabolic sounder antennas were buried in the ground and surrounded by absorber material to optimize isolation and minimize ground clutter. Brass models of battleships helped train early radars to recognize targets.

## 1975

**Thomas Russell founded Krytar** (Sunnyvale, CA), a company that helped define the performance of precision passive RF/microwave components. Starting with 18-GHz coaxial directional couplers, detectors, and power dividers, the company would advance its technology through the years to achieve coaxial directional detectors with upper-frequency limit to 110 GHz.


*(Courtesy of Krytar)*

## 1976

**Because of the** typical instability of frequency sources during that era, frequency counting with test instruments designed for that purpose was typically performed to characterize RF/microwave components and systems. As an example, the model 548A microwave frequency counter from EIP Microwave covered a frequency range of 10 Hz to 26.5 GHz with measurement resolution from 1 Hz to 1 GHz. Later that year, Hewlett-Packard Co. introduced the HP 8505A rack-mounted vector network analyzer (VNA) with range of 0.5 to 1300 MHz. It included a swept-frequency source, tracking receiver with 100-dB dynamic range, frequency counter, and autoranging voltmeter, with HP-IB.

## 1976

**Dr. James Truchard** started National Instruments in his garage as a part-time effort, along with co-founders Bill Nowlin and Jeff Kodosky, using computers as essential parts of test systems. That year was also a starting point for M.P.H. Industries (mphindustries.com), which introduced the model K-55 X-band (10.525-GHz) police radar with conical horn antenna as its first product. The company would develop a wide range of dashboard-mounted and handheld radar systems and displays, police LiDAR systems, and speed displays.

Sponsored by:

**Founded later in the decade** (January of 1979) in Beech Grove, Indiana; JFW Industries Incorporated thrives to this day as a leader in the design and manufacturing of RF attenuators, switches, power dividers and custom RF test systems.

**jfwindustries.com**

## 1971

**MITEQ, Inc.** began in 1971. Founded by former employees from Long Island, NY defense contractor Airborne Instruments Laboratory (AIL), including Frank Haneman and Aksel Kiiss, the company became well known for some of the industry's best-performing low-noise amplifiers (LNAs) and oscillators, guided by Kiiss and his loyal partner, wife Helle.

## EARLY 1970s

**Les Besser:** "The father of microwave computer-aided-design (CAD) software." Besser worked at Fairchild Semiconductor, Farinon Electric Co., and Hewlett-Packard Co., writing software in BASIC to help, for example, in solving for circuit-element values in transistor impedance-matching networks. His Computerized Optimization of Microwave Passive and Active CircuiTs (COMPACT) software followed from that earlier work.

*(Courtesy of NELC)*

## 1973

**Martin Cooper:** On April 3, 1973, Cooper, a senior engineer at Motorola, made the world's first mobile-phone call on a DynaTAC 8000X. The lucky recipient of the call was Joel Engel, the engineer leading AT&T's rival project; Cooper called Engel to gloat a bit. Cooper is widely regarded as the father of the cellular phone.

## 1972

**Q-Tech Corp.** was founded in 1972 and became the first company to commercially produce hybrid crystal oscillators and to appear on the MIL-PRF-55310 qualified products list (QPL) for such oscillators that were suitable for applications in military and space systems. In addition to hybrid crystal oscillators, the company has developed leading-edge oscillators with a wide range of logic types based on bulk-acoustic-wave (BAW) and surface-acoustic-wave (SAW) technologies.


*(Courtesy of Q-Tech Corp.)*

## 1977

**Based on building** a communications network with segmented, spread-out cells, Chicago, IL became a test site in 1977 for a concept proposed by Western Electric and Bell Laboratories in 1971. Chicago became Bell Telephone's first cellular network, using portable radios expensive for that time. This first-generation (1G) AT&T cellular system was known as the Advanced Mobile Phone Service (AMPS).

## 1977

**The British government** licensed two operators for its cellular communications network, eventually known as the Total Access Communications System (TACS). The two operators were Racal-Vodaphone Ltd., a joint venture between Racal and Millicon, and Telecom Securicor Cellular Radio Ltd., a joint venture between British Telecom and Securicor. TACS technology was based on AT&T's Advanced Mobile Phone Service (AMPS) first-generation (1G) cellular technology.

## 1977

*(Courtesy of the U. S. Air Force)*

**Westinghouse Electric Corp.,** Defense and Electronic Systems Center (now part of Northrop Grumman) delivered the first full-scale development radar (the AN/APG-66 pulse Doppler radar operating from 6.2 to 10.9 GHz) for the U.S. Air Force F-16 fighter to General Dynamics Corp. for integration. The X-band radar system, with a range of 150 km, featured extensive air-to-air and air-to-surface capabilities for navigation and weapons delivery even under harsh weather conditions.

## 1978

*(Courtesy of Rohde & Schwarz)*

**Since starting their company** in 1933, Dr. Lothar Rohde and Dr. Hermann Schwarz set new standards for measurement innovation with the first microprocessor-controlled 1-GHz analyzer. The company would double in size during the decade following 1973, building instruments with CAD-based circuit boards. The company has been incorporated in the U.S. since 1978.

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## 1980

**Test-instrument developer Tektronix** began the decade by acquiring Pentek and entering the spectrum analyzer business. As part of the deal, the venerable Morris Engelson joined Tek during a time in which the company introduced the programmable version of their popular 492 microwave spectrum analyzer, the model 492P. Designed in part to meet U.S. Navy needs, the analyzer reached 18 GHz with high resolution and accuracy. *(Courtesy of Tektronix)*

## 1980

*(Courtesy of Apollo Microwaves)*

**Apollo Microwaves Ltd.,** an early industry leader in mmWave components covering a total frequency range of 1 to 60 GHz, was founded in 1980. The ISO 9001:2008-certified company, with full in-house manufacturing and testing capabilities, designs and develops low-noise and high-power passive components, including antenna feeds, attenuators, couplers, phase combiners, and waveguide components for wireless and satellite communications (satcom) systems.

## 1980

**Started the previous year,** JFW Industries has grown into one of the industry's most dependable suppliers of passive components such as switches and attenuators. The ISO-9001:2015 registered company performs design, manufacturing, and test in-house at its Indiana-based facility.

## 1985

**Interest in GaAs semiconductors** during the 1980s drove some test instrument companies, including Hewlett-Packard Co. and Tektronix, to in-house development of GaAs IC technology. Tektronix would spin off its GaAs subsidiary in 1985 as TriQuint Semiconductor, around the same time that GaAs device maker ANADIGICS started. Hewlett-Packard Co. would introduce one of the most significant test instruments of the decade in 1985, the HP8510A vector network analyzer (VNA). Depending on test set, the VNA supported a growing GaAs market with S-parameter measurements over a frequency range as wide as 45 MHz to 26.5 GHz. *(Courtesy of Hewlett-Packard Co.)*

## 1984

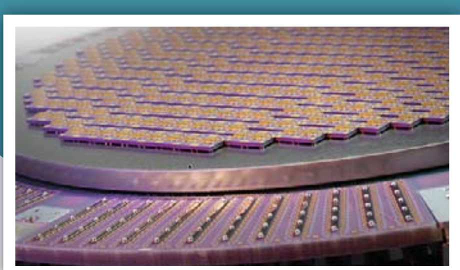
**A great deal of GaAs** device development focused on metal-epitaxial-semiconductor field-effect transistor (MESFET) structures. But Rockwell Science Center (Thousand Oaks, CA) took a different look at GaAs, using a more traditional bipolar device configuration, resulting in a GaAs heterojunction bipolar transistor (HBT) capable of a transition frequency ($f_T$) of 50 GHz.

## 1984

**Much of the "GaAs explosion"** of the 1980s was fueled by the U.S. Defense Advanced Research Projects Agency (DARPA) and its GaAs Microwave and Millimeter-Wave Monolithic Integrated Circuits (MIMIC) Program. Larger companies involved in GaAs included Hughes Aircraft Co., Raytheon Co., and TRW Semiconductors. Smaller companies included Alpha Industries, Avantek (acquired by HP/Agilent Technologies), Harris Microwave Semiconductor, M/A-COM, Motorola, Pacific Monolithics, Varian Solid State, Vitesse Semiconductor, and Watkins-Johnson Co.

## 1985

**Tektronix researchers** Eric Strid and Reed Gleason had an idea for products based on precision test probes in 1982, leaving Tektronix in 1985 with marketer Dale Carlton to start Cascade Microtech. The firm's precision test probes made it possible to characterize ICs while still on a GaAs wafer. Cascade Microtech is now part of FormFactor, which supplies advanced wafer probes and probe cards. Sierra Microwave Technology was also founded in 1985. *(Courtesy of FormFactor)*



## 1986

**Founded in 1982,** Microsource would revolutionize traditionally larger YIG filter and oscillator components with its MICRO YIG product lines. Components from 0.5 to 8.0 GHz were supplied as 1" cubes, while filters and oscillators operating to 24 GHz were available in 1.25" cubes. Microsource is now a division of Giga-tronics and works with additional filter and oscillator resonator technologies. But its YIG cubes enabled wideband microwave tuning in many commercial and military systems.

## 1987

**As wireless technology grew in popularity,** the Cellular Telephone Industry Association (CTIA) became more of a force and voice for the wireless industry, working with government agencies such as the FCC. Lark Engineering Co., founded in San Juan Capistrano, CA in 1987, grew steadily as a supplier of filters and other passive components for military and aerospace systems. The firm is now known as Benchmark Lark Technology.

*(iStock/Getty Images Plus, #937174970)*

# 60 YEARS



## 1981

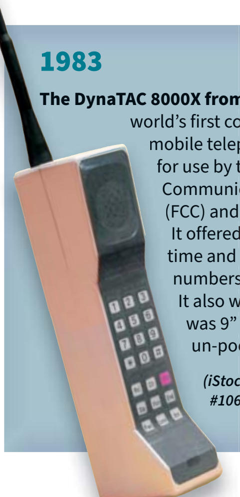
**The 1980s were** a time for exploring gallium-arsenide (GaAs) semiconductors. Seymour Cray designed a supercomputer with GaAs integrated circuits (ICs) to exploit the technology's speed advantages over silicon (Si) ICs. Cray-2 and Cray-3 computers required GaAs ICs from commercial suppliers, such as GigaBit Logic (Newbury Park, CA) and Pacific Monolithics (Sunnyvale, CA). The Cray-3 computer had a performance goal of 16 billion floating-point operations per second (16 GFLOPS) with a 2.11-ns clock cycle.

*(Courtesy of Digibarn and Stephen Gombosi of Associated Press)*

## 1981

**Technical editor Jack Browne** joined ***Microwave & RF***, known then as ***MicroWaves***, in mid-year, attending his first IEEE IMS Microwave Theory & Techniques Symposium (MTTS). He would create a third major section of the magazine, Product Technology, in addition to building the industry's company directory, the Product Data Directory, and starting several trade shows.

## 1983



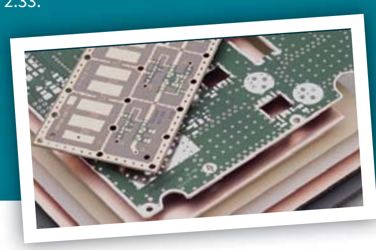
**The DynaTAC 8000X from Motorola,** the world's first commercial handheld mobile telephone, was approved for use by the U.S. Federal Communications Commission (FCC) and launched in the U.S. It offered 35 minutes of talk time and could store 30 phone numbers, all for just $3,995. It also weighed 2.5 lbs and was 9" tall, rendering it un-pocketable.

*(iStock/Getty Images Plus, #1069306208)*

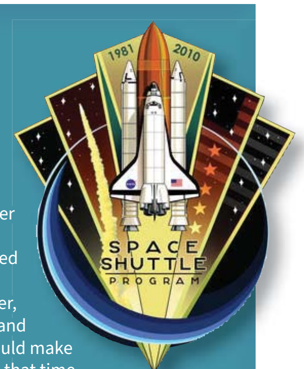
## 1983

*(Courtesy of Rogers Corp.)*

**Rogers Corp.** revolutionized high-frequency circuit design in the early 1980s with its introduction of RT/duroid laminates. The circuit materials consist of polytetrafluoroethylene (PTFE) composites with ceramic particles or glass fibers, such as the glass-fiber-reinforced RT/duroid 5870 with low loss, low moisture absorption, and low dielectric constant (Dk) of 2.33.



## 1982




**The 1980s and** the three decades from 1981 through 2011 became known as the "Space Shuttle era" for NASA's multiple launches per year. NASA's Space Shuttle fleet consisted of five spacecraft: Columbia, Challenger, Discovery, Atlantis, and Endeavor, which would make 135 missions during that time, aided by RF/microwave radar, guidance, and communications technology.

*(Courtesy of NASA)*

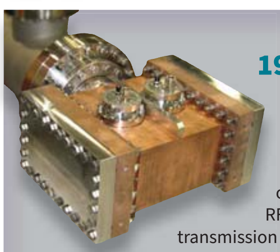
## 1988

**Engineers from M/A-COM PHI** reported on silicon DMOS FETs for L-band systems with capabilities to challenge silicon bipolar transistors at those frequencies. Developed with funding help from the U.S. Navy, the packaged DMOS FETs delivered 70 W output power from 1200 to 1400 MHz for a 1-ms pulse at 20% duty cycle.

## 1988

**Insulated Wire,** founded in 1970, expanded and created a microwave products division in Bethel, CT for coaxial cables, connectors, and coaxial assemblies capable of operating to 67 GHz and higher.

## 1989



**Mega Industries,** designer and manufacturer of high-power RF/microwave transmission lines such as waveguide and coaxial cable assemblies for broadcast, military, and space applications, was founded in 1989. The company's precision-machined waveguide components include the WR650 (100 to 1200 MHz) ultra-high-vacuum (UHV) directional coupler. *(Courtesy of Mega Industries)*

## 1989

**Planar Monolithics Industries, Inc. (PMI)** founded by **Dr. Ashok (Ash) Gorwara** on November 11, 1989, to take advantage of the growing demand in monolithic-based products using the Hybrid MIC/MMIC technology innovations that were mushrooming all over the world. PMI continues to offer state-of-the-art Hybrid MIC/MMIC Components and Subsystems to fit these applications.

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## 1990

**From its inception** in 1990, dB Control established itself as an important supplier of older technologies essential for military systems such as jammers and radars: traveling-wave tubes (TWTs) and traveling-wave-tube amplifiers (TWTAs). Now a subsidiary of the Electronic Technologies Group of HEICO Corp., dB Control is often a sole-source provider of TWTAs microwave power modules (MPMs) and other high-power components for military RF/microwave electronic systems.

*(Courtesy of dB Control)*

## 1990

**Also founded** in 1990, Micro Lambda Wireless built a business around YIG-based products, including filters, oscillators, and frequency synthesizers for commercial and military applications. Benchtop frequency synthesizers such as units in the MLBS series operate to 33 GHz. The industry's longest-running YIG supplier, Omniyig, started in 1973.

*(Courtesy of Micro Lambda Wireless)*

## 1991

**M/A-COM Inc.** developed the first cellular telephone handset GaAs IC, a transmit/receive (T/R) single-pole, double-throw (SPDT) switch. Four years later, the long-running semiconductor company with a history of RF/microwave switch ICs would be acquired by AMP Inc., which retained the M/A-COM brand.

*(Courtesy of Keysight Technologies)*

## 1994

**Filtronic Comtek plc** was organized from portions of the original firm and listed on the London Stock Exchange. It would grow rapidly into the 2000s, acquiring several companies including Litton Solid State and its GaAs foundry in 1998. Litton was a key developer of innovative components for Northrop Grumman, including the model LN-200C fiber-optic gyro, which could measure velocity and changes in angular degrees. *(Courtesy of Filtronic)*

## 1995

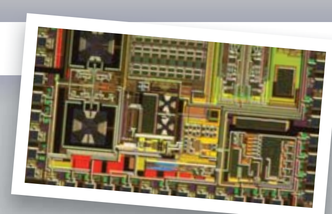
**Elcom Technologies (Rockleigh, NJ)** was founded in 1995 as an innovative developer of fast-switching, low-phase-noise frequency synthesizers for ELINT, SIGINT, and ATE applications. Following a strategic partnership with Frequency Electronics Inc. (FEI) in 2007, Elcom Technologies was acquired by FEI in 2012 to become what is presently FEI-Elcom Tech Inc., a wholly-owned subsidiary of FEI.

## 1996

**Starting in 1996** in Elmsford, NY, HYPRES brought a unique command of cryocooled superconductors to the RF/microwave industry, using cold operating temperatures to effectively eliminate circuit loss and signal noise. Offering sensitive receiver solutions to space and military customers, the company's flagship product is its model HYDR-02 advanced digital RF receiver (ADR), which can directly digitize RF signals over wide bandwidths surrounding a center frequency of 21 GHz. *(Courtesy of HYPRES)*

## 1997

**By its fifth year,** the growth of the Wireless Symposium & Exhibition mirrored the rapid expansion of the RF/microwave industry in wireless markets, including in battery technologies for portable electronic products. A diversified technical program covered device and circuit design, modulation, materials, packaging, and measurement approaches from industry leaders, including Hewlett-Packard Co., IBM Microelectronics, LeCroy Corp., Lucent Technologies, and Motorola Semiconductor.

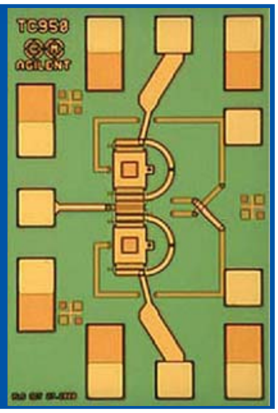


## 1998

**After many years** of working with silicon-germanium (SiGe) semiconductor processing in its own research laboratories, IBM acquired CommQuest Technologies, a developer of ICs for Global System for Mobile Communications (GSM) cellular communications handsets. SiGe technology supports dense circuits and such features as RF amplifiers with better power-added efficiency (PAE) than GaAs semiconductor processes. SiGe would become a mainstay for many semiconductor suppliers, including Analog Devices, Maxim Integrated Products (now part of Analog Devices), Microsemi, and RF Micro Devices. *(Courtesy of IBM)*

## Did You Know?

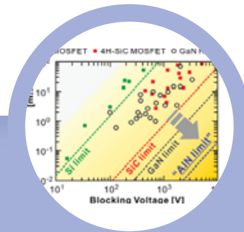
**Frequency letter bands** were designated by engineers at Fort Monmouth, NJ during World War II; these designations were classified at that time. Rather than a logical A-B-C progression, the engineers chose designators like L, C, X, and K, which, according to legend, were meant to confuse the enemy. The U.S. government didn't declassify the details until after the war, leaving commercial entities to make educated guesses as to what the designators meant. Therefore, no industry-wide standard for the letter bands emerged until the ITU brokered an agreement in 1959.



### 1992

**Maury Microwave,** long a leading developer of load-pull and impedance tuners for precision linear and nonlinear measurements, made noise with the introduction of its model MT2075B05 noise gain analyzer for highly accurate noise and power measurements through mmWave frequencies.

*(Courtesy of Maury Microwave)*




### 1992

**Wide-bandgap semiconductors:**
With silicon-based power transistors reaching their limits in terms of operating frequency, breakdown voltage, and power densities, wide-bandgap semiconductor technologies such as gallium nitride (GaN) have gained favor in RF signal processing thanks to their ability to withstand high temperatures and handle larger voltages in power-amplifier applications.

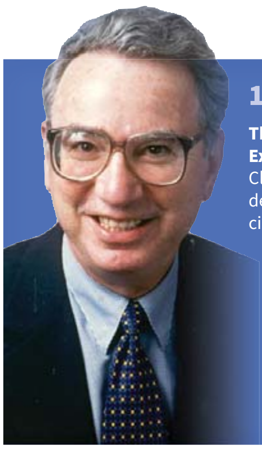
### 1993

**Times Microwave Systems** introduced LMR coaxial cables, which would turn into one of their best-selling product lines. The 50-Ω cables would become standard flexible transmission lines for antenna-to-transceiver connections in wireless cellular base stations.

*(Courtesy of Times Microwave Systems)*

### 1993

**Anritsu Co.,** a leading test instrument manufacturer from Japan founded in 1895, would make its move into the U.S. microwave test and measurement market with the acquisition of Wiltron Co. (Morgan Hill, CA) and its microwave and mmWave signal sources and vector network analyzers (VNAs).



### 1993

**The Wireless Symposium & Exhibition** was launched in Santa Clara, CA as a new trade show for designers of wireless communications circuits and systems. The first keynote speaker, Irwin Jacobs, founder and CEO of Qualcomm, welcomed attendees with the foresight that cellular wireless communications markets would drive RF/microwave component and device sales for years to come.

*(Image copyright held by IEEE)*

*(Courtesy of Iridium)*

### 1998

**Towards the end of the year,** Iridium LLC launched commercial services with a constellation of low-Earth-orbit satellites (LEOS). Beginning 10 years earlier as a Motorola research lab, the company was based on achieving high-speed communications by surrounding the planet with 77 LEOS (although "only" 66 were needed). Iridium would declare bankruptcy the following year but was saved by investors and partnered with SpaceX in 2010 to achieve its current success.

### 1999

**Anokiwave was founded** at the end of 1999 by its CTO, Nitin Jain, formerly of M/A-COM. He and the company functioned as design consultants for mmWave circuits and devices such as 77-GHz vehicular radars. With the help of several rounds of funding, the company has grown into an innovative developer of silicon-based antenna-based RFICs for commercial and military applications, including antenna beamforming ICs and phased-array antenna kits. *(Courtesy of Anokiwave)*

### 1999

**At the end of 1999,** Agilent Technologies was spun off from Hewlett-Packard Co. as a record-setting initial public offering (IPO) that raised over $2 billion USD (compared to the $538 in working capital that Bill Hewlett and Dave Packard had to start the company in 1938). By 2014, Agilent would spin off Keysight Technologies, with Agilent managing biotechnical, chemical, life sciences, gas chromatography, and medical products, and Keysight taking with it all the design software and test and measurement products.

*(Courtesy of Agilent Technologies)*

# Microwaves & RF®

*A look back at the people, products, and technologies that have impacted our industry.*

## 2000

**With an initial public offering** (IPO) of Agilent Technologies in November 1999, Hewlett-Packard Co would raise $2.1 billion. Hewlett-Packard would then spin off Agilent Technologies in June 2000 through the distribution of Agilent shares to Hewlett-Packard shareholders. Agilent Technologies would continue developing electronic test equipment and software while expanding into life-science markets. Sadly, life ended for one of HP's founders, William Hewlett, a year later.

*Dave Packard (left) and Bill Hewlett (right).*

*(Courtesy of Agilent Technologies)*

*(Courtesy of Bing)*

## 2001

**MEMtronics** was incorporated to commercialize microelectromechanical-systems (MEMS) technology. The company's tiny integrated waveguide MEMS filters compete in size with printed-circuit microstrip and stripline filters but with the loss and rejection performance of much larger metal waveguide filters.

*(Courtesy of MEMtronics)*

## 2007

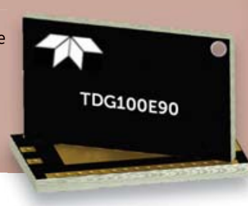
**In August,** Ajay Poddar and Ulrich Rohde of Synergy Microwave Corp. presented a patented technique to reduce phase noise in voltage-controlled crystal oscillators (VCXOs) even as they shrink in size and power consumption.

*(Courtesy of Synergy Microwave Corp.)*

*(Courtesy of Rohde-Foundation)*

## 2006

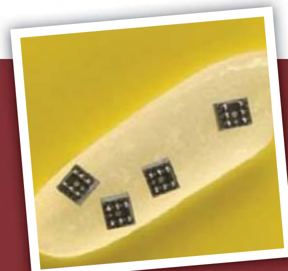
**Cree Santa Barbara Technology Center** in Goleta, CA (now Wolfspeed) presented one of the highlights of the 2006 International Electron Devices Meeting (IEDM) with its unveiling of a compact amplifier built with just two GaN HEMT devices but capable of 550 W peak power at 3.5 GHz for radar applications. Newer developments in GaN HEMTs include a 100-V device and 650-V power transistors from Teledyne Defense Electronics.




*(Courtesy of Teledyne Defense Electronics)*

## 2005

**Agilent Technologies** shipped its 100-millionth film-bulk-acoustic-resonator (FBAR) filter, just four years after it was developed in 2001, with a production rate of more than 6 million FBAR filters/month. The filters, measuring 1.6 × 2.0 mm, are used in cellular handsets and other mobile wireless devices.



*(Courtesy of IEEE)*

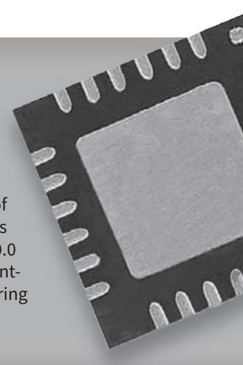
## 2007

**Maxim Integrated Products,** now part of Analog Devices, introduced the industry's first single-chip silicon-germanium (SiGe) BiCMOS transceiver for WiMAX. Now obsolete, the original model 2837 IC has been replaced by the company's model MAX2839 IC for MIMO applications from 2.3 to 2.7 GHz.


*(Courtesy of Maxim Integrated Products, now part of Analog Devices)*

## 2008

**The model HMC613LC4B** surface-mountable, successive-detection, log-video amplifier (SDLVA) from Hittite Microwave (now part of Analog Devices) set new levels of performance from 0.1 to 20.0 GHz in a 24-lead surface-mount-device (SMD) package measuring just 4 × 4 mm.



*(Courtesy of M/A-COM)*

## Did You Know?

**Women have made many contributions** to the microwave & RF industry, but one you may not know of is Dr. Gladys West, who was among the so-called "hidden figures" who did computational work for the U.S. military in the era before computing systems were widely used. Dr. West's mathematical work laid the groundwork for the invention of the Global Positioning System (GPS); she programmed the IBM 7030 "stretch" computer that produced a refined version of a geodetic Earth model. She was inducted in 2018 into the Air Force Space and Missiles Pioneers Hall of Fame for her contributions.

*Source: https://insights.dice.com/2020/03/06/13-famous-women-changed-tech-history-forever/?wpse_show_all_content=1*

### 2002

**Skyworks Solutions** started from the merger of RF/microwave analog semiconductor supplier Alpha Industries and the wireless communications division of Conexant. The resulting public company provides high-performance analog ICs for many markets, including aerospace/defense, automotive, medical, wireless mobile communications, and optical networking.

*(Courtesy of Skyworks Solutions)*

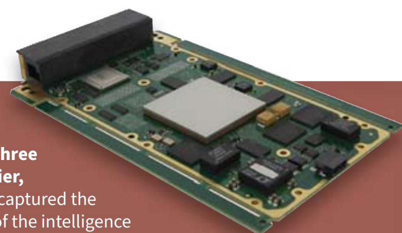
### 2003

**The RF/microwave industry** lost one of its leaders and top minds with the passing of Bruno Weinschel in 2003. Dr. Weinschel came to the U.S. from Stuttgart, Germany in 1938, spending several years with Bell Laboratories and the National Bureau of Standards (NBS) before starting Weinschel Engineering in 1952. He was an IEEE Fellow and served as IEEE President in 1986. Weinschel Engineering was sold to Lucas Aerospace in 1986; Dr. Weinschel started Weinschel Associates in 1989.

*(Courtesy of Weinschel Associates)*


### 2004

**Cellular mobile network** 4G development began in 2004, and its arrival made smartphones and hand-held mobiles truly possible. Long-Term Evolution (LTE) technology brought theoretical download speeds from 10 Mb/s to 1 Gb/s. 5G technology development started in 2008; it first appeared commercially on April 3, 2019 in South Korea, followed by Verizon's 5G launch in the U.S. just hours later.



### 2004

**Founded three years earlier,** LNX Corp. captured the attention of the intelligence community with its model RX00103-005 rack-mountable digital receiver. It directly sampled signals from DC to 3 GHz with a sampling rate of 2 GS/s. LNX would be acquired by Mercury Systems in 2011, the first of a long list of acquisitions by Mercury that included Micronetics, Delta Microwave, and, most recently, Pentek. Modular versions of that digital receiver based on Intel Core i7 microprocessors provide many times the processing power in a fraction of the size.

*(Courtesy of Mercury Systems)*

### 2008

**NXP and STMicroelectronics** combined their wireless technology operations as a joint business capable of filling the high-volume needs of fast-growing wireless applications, such as 2G and 3G handsets. The merger included the wireless business unit of Silicon Laboratories and the GPS operations of GloNav previously acquired by NXP.

### 2009

**The MS4640A line** (since replaced by the MS4640B series) of VectorStar vector network analyzers (VNAs) from Anritsu Co. (formerly Wiltron Co.) set new levels of performance in the RF/microwave industry with over 120 dB of dynamic range to 20 GHz.

*(Courtesy of Anritsu Co.)*

# Microwaves & RF®

*A look back at the people, products, and technologies that have impacted our industry.*

## 2010

**Micro Lambda Wireless** set new standards for the small size of permanent-magnet YIG-tuned oscillators with the introduction of their MLTO series. The microwave oscillators fit into tiny 0.5" diameter TO-8 packages. The company, which offers cross-reference models for classic Avantek YIG oscillators, maintains a leading role in YIG filter and source technology development.

*(Courtesy of Micro Lambda Wireless)*

## 2011

**National Instruments**, a leading producer of PXI modular test instruments, continued its growth into the RF/microwave frequency spectrum with the acquisition of Phase Matrix. Acquisition of the fast-switching frequency synthesizer developer, which will operate as a wholly owned subsidiary, extends the combined business to component and instrument technologies at 26.5 GHz and higher in frequency. *(Courtesy of NI)*

## 2011


**As Narda-Microwave,** the company had been part of the industry since the first days of ***Microwaves & RF***. As the industry explored new markets, Narda Safety Test Solutions reached medical customers with their Nardalert S3 radiation monitor, recently upgraded to the 5G mmWave frequency range. The wearable sensor detects unsafe levels of EM radiation from 100 kHz to 100 GHz. Narda-STS is now part of L3 Harris.

*(Courtesy of Narda Safety Test Solutions)*

## 2016

**A report on** medical applications for microwave technology highlighted how companies such as Emblation Microwave were applying newer semiconductor technologies such as GaN on SiC to build solid-state sources for microwave ablation, such as the MSYS245 with 100 W at 2.45 GHz.

*(Courtesy of Emblation Microwave)*

## 2016

**The trend in smaller,** battery-powered test instruments was clear with Tektronix's introduction of the RSA507A real-time spectrum analyzer (RSA). With a laptop computer, the USB-compatible instrument scans 9 kHz to 7.5 GHz in a fraction of the size of a traditional RSA. That same year, Anritsu would launch its Power Master MA24507A, a pocket-sized power analyzer with frequency range of 9 kHz to 70 GHz.

*(Courtesy of Tektronix)*

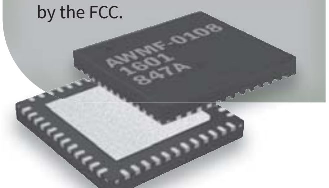

## 2015

**As the merged** TriQuint Semiconductor and RF Micro Devices, Qorvo expanded its in-house GaN-on-SiC foundry from 4" to 6" diameter wafers. Soon after, Qorvo introduced RF Flex front-end ICs to aid in the evolution of cellular wireless from 4G to 5G.

*(Courtesy of Qorvo)*

## 2016

**Industry's 1st** 28-GHz silicon beamformer IC from Anokiwave enabled the mmW 5G market to prepare for the first wave of developments even before spectrum was officially allocated by the FCC.




## 2017

**Newcomer Anokiwave** added innovation to antenna design though the use of their active antenna beamsteering ICs. By working with Ball Aerospace, they developed a compact planar-array antenna for 28-GHz use. The active array supports hybrid beamforming and MIMO applications from 27.5 to 30.0 GHz.

*(Courtesy of Anokiwave)*



## 2018

**As one of hundreds** of exhibitors at a bustling pre-COVID-19 2018 IMS Symposium & Exhibition in Philadelphia, PA, SiTime grabbed the attention of many visitors with its MEMS oscillator technology. Its model SiT5356 temperature-compensated crystal oscillator provides LVCMOS outputs from 1 to 60 MHz tunable in 1-Hz steps with a mere 0.31-ps phase jitter, all in a 10-pin package measuring just 5.0 × 3.2 mm. The company has significantly impacted the timing industry with its MEMS technology.

*(Courtesy of SiTime)*

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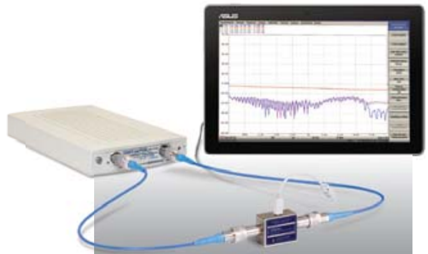


**In 2011, Copper Mountain Technologies** pioneered the industry's first metrology-grade USB VNA. This gave users access to affordable, portable instrumentation without sacrificing performance. Since then, CMT has empowered engineers through flexible VNA solutions backed by comprehensive support from expert applications engineers. CMT's evolving catalog of 30+ instruments and application specific solutions continues to expand VNA use into previously untapped industries.

**coppermountaintech.com**

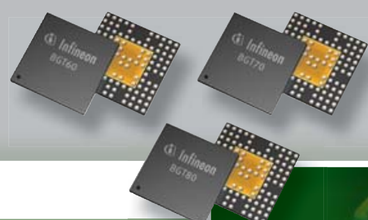
## 2012

**Boeing Co.** and the U.S. Army's Space and Missile Defense Command (SMDC) worked on directed-energy weapons (DEWs) under phase II of the High Energy Laser Mobile Demonstrator (HEL MD) contract. Boeing's Directed Energy Systems (DES) division worked with BAE Systems on the contract for SMDC.

*(Courtesy of Boeing Co.)*

## 2013

**With the impending bandwidth needs** of 5G wireless networks, Infineon Technologies introduced its BGT family of front-end ICs for mmWave backhaul links in the 60-, 70-, and 80-GHz bands. The ICs were based on a silicon-germanium (SiGe) semiconductor process with transition frequency ($f_T$) of 200 GHz. *(Courtesy of Infineon)*




## 2014

**Vectron International** attracted visitors to its booth at the IMS in Tampa Bay, FL with a new line of oscillators based on microelectromechanical-systems (MEMS) technology. They are available from 1 to 137 MHz and supplied in packages ranging in size from 2.0 × 1.6 × 0.75 mm to 5.0 × 7.0 × 0.90 mm.

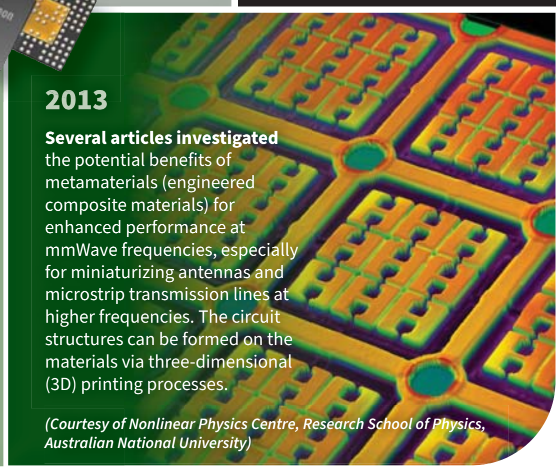
*(Courtesy of Vectron International)*

## 2014

**Reaching real-time bandwidth** of 100 GHz at a sampling rate of 240 Gsamples/s, the LabMaster 10-100Zi real-time oscilloscope (RSO) from Teledyne LeCroy was designed with a modular format to simplify upgrades.

*(Courtesy of Teledyne LeCroy)*

## 2013



**Several articles investigated** the potential benefits of metamaterials (engineered composite materials) for enhanced performance at mmWave frequencies, especially for miniaturizing antennas and microstrip transmission lines at higher frequencies. The circuit structures can be formed on the materials via three-dimensional (3D) printing processes.

*(Courtesy of Nonlinear Physics Centre, Research School of Physics, Australian National University)*

## 2019

**News from Lockheed Martin** and the U.S. Army reported on high-energy lasers (HELs) and how energy efficiency of these systems was being boosted enough to make them transportable and usable in the field against targeted vehicles. The initial research has led to the development of the present-day ATHENA directed-energy-weapons system for use against unmanned aerial vehicles (UAVs).

*(Courtesy of Lockheed Martin)*

## 2020

**Anritsu** debuts its VectorStar ME7838G broadband vector network analyzer, which is the industry's first VNA capable of making measurements from 70 kHz to 220 GHz in a single sweep.

## 2020

**Xilinx** rolls out its Zynq RFSoC digital front end (DFE), which combines hardened DFE IP blocks with a programmable, adaptive SoC that fits all use cases across the 5G spectrum.

DAVE BARRY, HUGO MORALES, CHRIS DeMARTINO | Modelithics

# Improve Simulation with 3D QFN-Package Models

**An assortment of 3D models for QFN packages enable designers to predict performance for a wide range of scenarios via full-wave 3D EM simulations.**

Quad-flat no-leads (QFN) packages are commonly used for RF applications to connect integrated circuits (ICs) to printed-circuit boards (PCBs). The benefits associated with QFN packages include low cost, a small form factor, and good electrical and thermal performance. QFN packages come in various sizes, typically ranging from 3 × 3 mm to 9 × 9 mm.

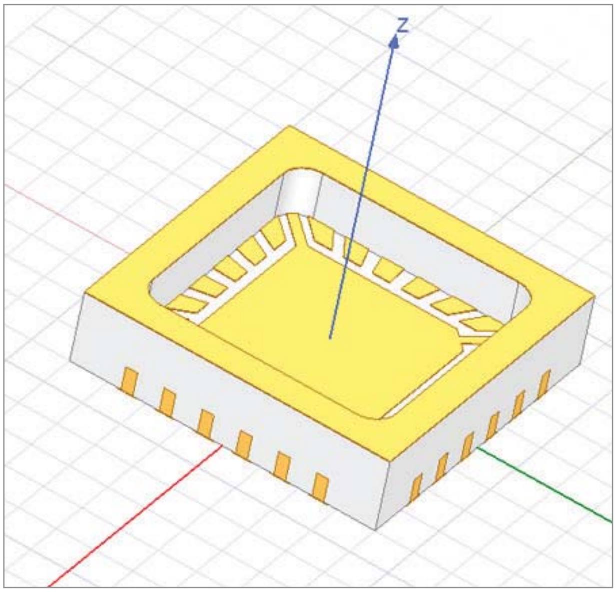
One company that manufactures QFN packages is Barry Industries, which offers versions rated to 40 GHz. In contrast to plastic QFN packages, Barry builds high-temperature co-fired-ceramic (HTCC) versions that feature low-loss broadband transitions, allowing for superior performance over frequency. These packages also withstand much greater temperatures than plastic QFN packages and can be sealed hermetically.

Barry's QFN packages come in six sizes that range from 3 × 3 mm to 8 × 8 mm. Each package size is available in any of three different configurations: bare seal ring, grounded seal ring, and castellated grounded seal ring.

Bare seal ring, an epoxy or glass-lid-attachment configuration, is the lowest cost of the three options. Grounded seal ring is a solder-lid-attachment configuration. Castellated grounded seal ring also is a solder-lid-attachment configuration, but it includes castellations that allow solder fillets to form, thus making it possible to visually inspect pin solder joints. This configuration is the most expensive, too.

Barry Industries and Modelithics are partnering to offer 3D geometry models for Barry's QFN packages *(Fig. 1)*. These models are intended for use with Ansys HFSS and are available in the latest version of the Modelithics COMPLETE+3D Library.

In addition to the 3D geometry models, designers should be aware that Modelithics offers equivalent-circuit models for many of these same packages. These equivalent-circuit models were created using Ansys HFSS 3D simulation data after validating EM simulations with lab measurements for several test conditions. In total, 18 Barry QFN packages are represented with both a 3D geometry model and an equivalent-circuit model.




**1. Shown is the Modelithics 3D geometry model for the QFN-4424-0522, which is a 4-mm QFN package with a castellated grounded seal ring configuration. This model is validated from dc to 40 GHz.**

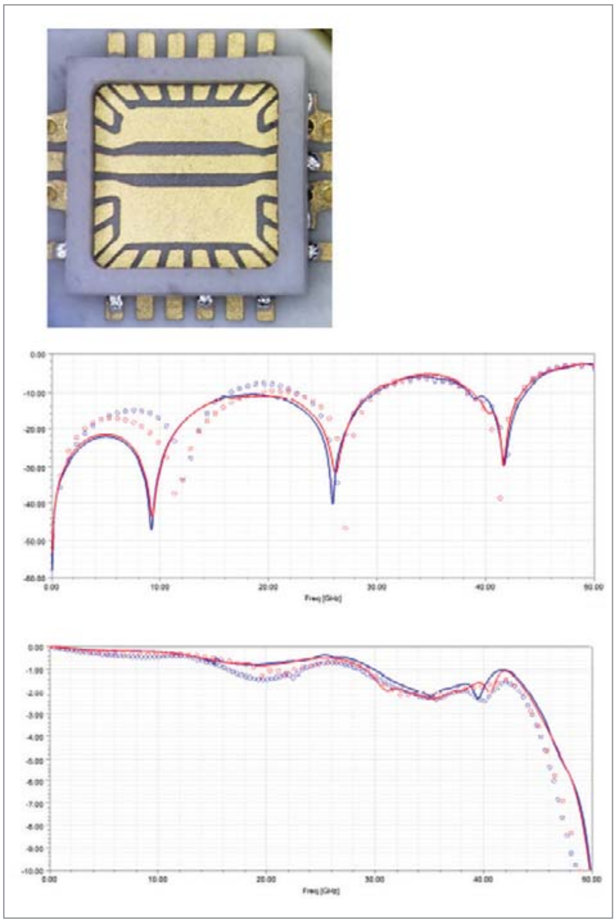
## Advantages of 3D Models

3D geometry models are intended for use in full-wave 3D electromagnetic (EM) simulations. They enable designers to predict coupling effects that can occur when components are located close to other components or objects (3D models for Barry packages predict coupling effects within the package and outside the package body).

However, such effects can't be captured when using equivalent-circuit models. 3D geometry models, which are included as part of a custom HFSS library, are based on physical dimensions and material properties and are encrypted to protect manufacturer IP.

In the case of the Barry 3D package models, for instance, designers don't have access to material properties due to encryption but do have access to all package pins—both inside and outside *(Fig. 1, again)*. Therefore, users can load the model in an EM environment and optimize the PCB layout for the best performance (more on this later). Designers also can optimize matching inside the package by utilizing carefully selected wire shapes, ribbons, and so on.

In addition, since designers have access to all pins, the models allow for a great deal of flexibility. Pins can be terminated (inside and outside) as needed to achieve optimal performance.



**2. On the top is a 4-mm package with a custom built-in matched line. The graphs in the middle and on the bottom depict measured and simulated $S_{11}$ and $S_{21}$, respectively. The solid lines represent simulated results, while the symbols represent measured data (blue is for microstrip; red is for GCPW).**

With these 3D package models, designers are able to combine pins for RF signals, utilize certain pins for dc bias lines, and optimize grounding patterns to meet design requirements.

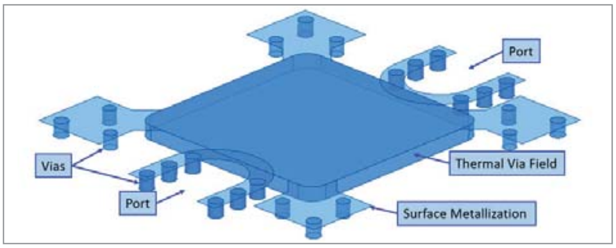
It should be noted that Modelithics 3D package models are well-suited for co-simulations. For example, say a designer has access to a MMIC amplifier's S-parameter data. The designer could then create a simulation project in which the MMIC amplifier is mounted inside the package. Bond wires would be used to connect the amplifier to the package. Then a co-simulation could be performed that involves simulating the package and bond wires in HFSS. Ports also must be added to enable co-simulation. Subsequently, the MMIC amplifier's S-parameter data would be connected to the ports to enable a co-simulation.

In a similar manner, 3D package models can be combined with Modelithics equivalent-circuit models for capacitors. To summarize, the co-simulation process involves combining 3D EM simulation data with S-parameter data or circuit models associated with fast optimization.

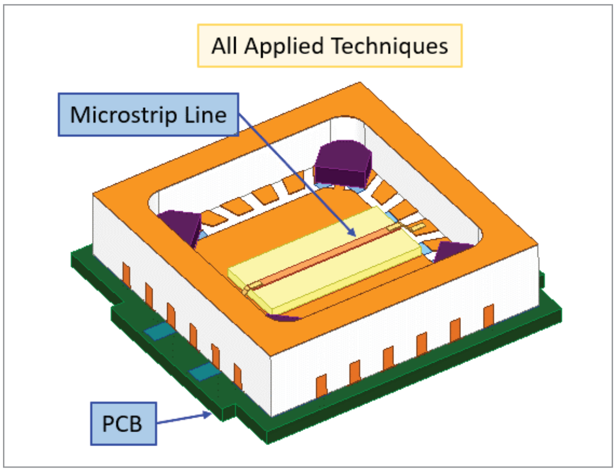
### Measurement Validations

Of course, when possible, it's recommended to compare simulated results with measured data for additional validation. In this case, we analyzed a 4-mm package with a custom built-in matched line.

*Figure 2* shows the package along with graphs that illustrate both simulated results and measured data. We used both microstrip and ground coplanar-waveguide (GCPW) configurations. 3D models can be considered as value-added tools that allow designers to optimize PCB footprints. For this analysis, we optimized performance through proper grounding, which is discussed in detail on the following page.




3. This PCB ground pattern should be employed to suppress the unwanted resonances.




4. Shown is a simulation model of the complete package with all mitigation techniques applied. Mounted inside the package is an alumina board with a microstrip transmission line that's ribbon-bonded to the package pins.

### Performance Hurdles

In broadband package designs, designers may want to have resonance-free performance. The nature of the package geometry results in multiple unwanted resonances. Therefore, several mitigation techniques are recommended to suppress the resonances and achieve best performance. These mitigation techniques have been realized through extensive simulations with the 3D models.

One of the specific features that contributes to the package resonances is pin-to-pin proximity. Specifically, the pins in the QFN-4424-0522 package are located 0.5 mm apart from one another. This 0.5-mm spacing between pins results in strong coupling. Multiple adjacent pins form a periodic structure that results in both higher- and lower-frequency resonances.

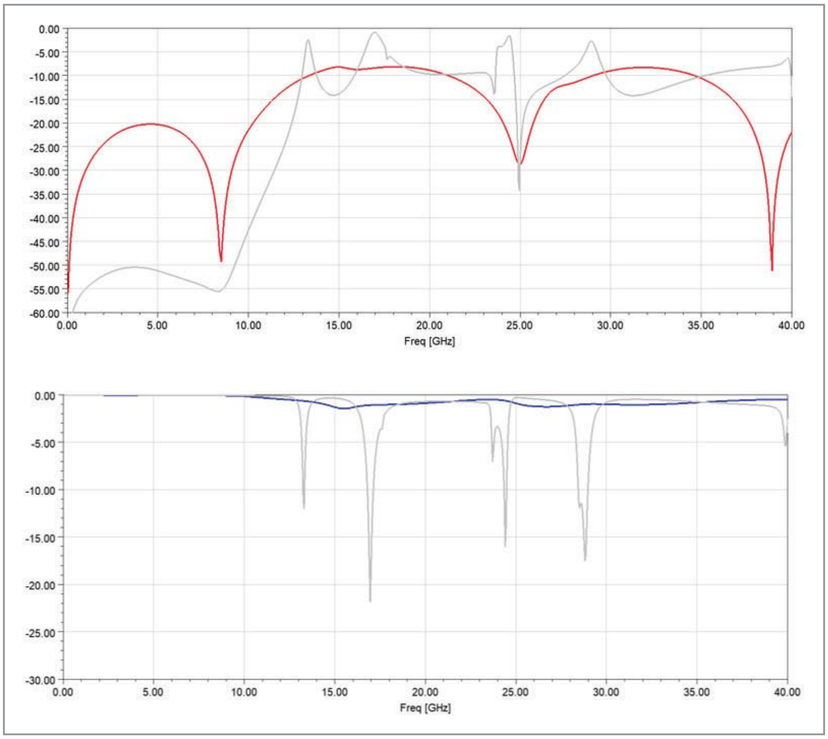
Packages that rely on a metallization ring to attach the cover exhibit additional resonances. The next section focuses on removing unwanted resonances within the frequency band of interest.

### Techniques for Using the 3D Package Models

As stated, removing the unwanted resonances require several mitigation techniques to be applied. For one, it's recommended to ground the package pins located adjacent to the RF signal pins both internally and externally. The ground vias should be in the form of a "pin triplet" (to be shown later). Another possible mitigation technique involves attaching a microwave absorber (i.e., Emerson Cummings MF190 or similar) to the metallization in each of the four corners to avoid resonances associated with the metallization ring.

Additional mitigation techniques include grounding the corner pins using the same grounding method applied to the pins adjacent to the signal pins. To ground the corner pins, one should employ enough PCB surface metallization and ground vias. Sufficiently grounding the corner pins helps to suppress the effects of the metallization ring.

*Figure 3* illustrates both how the corner pins should be grounded and the aforementioned "pin triplets" employed to




5. The top graph presents the $S_{11}$ results after simulating the package both with mitigation techniques (red trace) and without them (gray trace). The $S_{21}$ results are shown in the bottom graph, again both with mitigation techniques (blue trace) and without them (gray trace).

ground the pins adjacent to the signal pins. Grounding of corner pins is available to designers, particularly when pins aren't used for dc lines or other functions. Therefore, the user can evaluate extended design requirements when using these 3D models.

### Analyzing the Package with All Mitigation Techniques

*Figure 4* shows a simulation model of the QFN-4424-0522 package implementing all of the mitigation techniques. Mounted inside the package is an alumina board with a microstrip transmission line. This board is ribbon-bonded to the package pins.

*Figure 5* shows the simulated $S_{11}$ and $S_{21}$, revealing performance free of any unwanted resonances. However, while no resonances are present, one would still want to incorporate proper matching to improve the return loss. For comparison, *Figure 5* also shows the package performance without any mitigation techniques.

In conclusion, those in need of simulating circuit designs inside of QFN packages may want to consider taking advantage of Modelithics 3D models for Barry packages ranging in size from 3 × 3 to 8 × 8 mm. These models are intended for use in Ansys HFSS. In addition, the mitigation techniques shown here can help users achieve best performance all the way to mmWave frequencies. ■


AUTHORS

DAVID E. BARRY began working for Modelithics in April 2021 as a Senior Member of the Technical Staff where he provides 3D RF electromagnetic modeling capability. He has also coupled thermal and power analysis to the modeled performance. David specializes in RF/microwave component design and modeling in a wide range of architectures and materials.

HUGO MORALES is the VP of Engineering at Modelithics in Tampa, FL. He has been with Modelithics since 2006, leading and managing projects while supporting microwave/mmWave linear and nonlinear measurements, and modeling of passive, test fixture, and active microwave components.

CHRIS DEMARTINO began working in the RF/microwave industry in 2004, developing and testing a variety of RF/microwave components and assemblies for both commercial and military programs. In May 2015, DeMartino joined *Microwaves & RF* magazine, where he served as the technical editor. In December 2019, he joined Modelithics as the company's sales and applications engineer.



ACKNOWLEDGEMENT

The authors would like to thank Eric Valentino, formerly with Modelithics, for his contributions to this work.

ALIX PAULTRE | Writer, Editor, Technologist


Skymediapro | Dreamstime.com

# The Importance of RF Filters in Advanced Wireless Systems

**How can today's wireless systems best meet user expectations? Resonant's Mike Eddy weighs in on that question and provides insight into the company's new RF filter that leverages the firm's XBAR technology.**


**Mike Eddy, VP of Corporate Development, Resonant**

The explosion in growth of cloud-enabled IoT-focused products and solutions is causing even more traffic in our already crowded airwaves. If the radio spectrum could be thought of as a highway, and the bands as lanes in it, RF filters keep the signal "between the lines" so that data moves with minimal collisions or interference. RF filters are among the key core technologies to address next-generation systems that need high RF performance, such as autonomous vehicles, telemedicine, smart facilities, and other highly connected apps.

One of the companies operating in the space, Resonant, recently released a new RF filter, designed with the company's proprietary XBAR technology. We talked to Mike Eddy, the VP of Corporate Development at Resonant, to get a better idea on how the company's advanced RF filter technology can enable next-generation wireless products and solutions.

**Hi Mike! I understand Resonant recently held a "Breaking Through the Noise of 5G in Europe" webinar series. Considering all of the pressures on wireless developers, ensuring optimal wireless performance has to be paramount. What are some of your impressions from the event series?**

Thanks for having me. The webinar series featured industry experts who discussed the evolution to 5G, some of the drivers of 5G adoption, the continued role of 4G, next-generation Wi-Fi, with particular emphasis on the status of 5G in Europe. What I got was that Europe is moving much more aggressively now on the first key piece of any new wireless technology, which is allocating spectrum. So you see over the first half of 2021, several countries, both in the EU and the UK, are actually auctioning off spectrum in the key bands, and particularly the mid-band, 3.4 GHz to 3.8 GHz.

Europe did a really, really good job of realizing that they needed to—what they call harmonize bands to 5G. What they did is they said, "Okay, we're going to call these the pioneer 5G bands and come up with a strategy where you can get full coverage. You can get high-speed data wirelessly, and localized you can get extremely high speed." And that's related to the different frequency bands. So they knew that 700 MHz, 3.4 to 3.8 GHz, and millimeter-wave 26-GHz bands as a strategy to really take advantage of 5G.

So what you're seeing right now in Europe is they are particularly sensitive to the situation with Huawei. Most of the 4G infrastructure in Europe is Huawei. 5G and the initial rollout needs to work with 4G, and therefore many countries are trying to decide what to do about whether they're going to have a new contract with Huawei, or whether they're going to take a different tack and use some of the other major players. So Europe was kind of behind China and the U.S., but now, after COVID, seems to be easing a little bit, there seems to be a real aggressive push now to roll out 5G in Europe. And as you said, what that means for everybody is crowded airwaves.

**How much has this issue with Huawei been a technical issue, and how much of it is a political issue? Recognizing that we're not going to go deeply into politics, I just wanted to nod in that direction and recognize that this is bigger than just engineering.**

Absolutely. It is more political than technical. Obviously there are issues around the security of these major infrastructures, but a lot of it is political and there is pressure in Europe to move away from Huawei infrastructure. There are not a lot of options now, but will increase as we move to what's called an Open RAN, a more open architecture.

**This would almost be a perfect storm for a peer-to-peer architecture to suddenly materialize. I can remember in the early days of the web, where there were companies who were trying to develop a peer-to-peer architecture that would run concurrently with, or under the layer of, the internet and the grid that we know of, with just unit-to-unit comms. In other words, creating a mesh network through the IoT devices themselves.**

That's a great point. The need for low latency in 5G is dramatically changing the architecture for infrastructure. So, the cloud and compute needs to go closer to the user to improve latency, which means then that architecture has to change. And that opens up the opportunity for a different kind of network. Although it's difficult to see how you can not use some of the major players, there is a move by the major operators to try and use a much more distributed and open architecture, which is what's called Open RAN.

> "The need for low latency in 5G is dramatically changing the architecture for infrastructure. So, the cloud and compute needs to go closer to the user to improve latency, which means then that architecture has to change."

The newer players are much more open to using this new architecture. For example, Dish, which is kind of a new fourth operator, has decided to use this Open RAN architecture. One thing when you're talking about a more distributed architecture and compute and cloud close to the user, it means you have to partner with some of the major hyperscalers who are much more used to cloud computing. There are a lot of partnerships being announced, Amazon's AWS, Microsoft's Azure. They're all working with the major operators to help them change that architecture to a much more open and distributed architecture.

**It only benefits everybody, right?**

Correct. It ultimately will mean the experience is much better for the consumer. And ultimately it'll mean that it's a much lower cost to grow a network.

**Now, having said all of that, that brings back into focus the issue of the crowded bandwidth, and staying in your lane, and making sure everything is done precisely. What are your thoughts on that?**

We talked how the airwaves are getting more and more crowded and you need to keep your signals in the correct lanes in order to take full advantage of these frequency bands. Whether that's 5G, whether that's the new Wi-Fi bands, for instance at 6 GHz, which are being allocated now both in the U.S., Canada, Brazil, and in Europe, and also ultra-wideband, which is being used now in phones above the 6-GHz band.

All of these bands are being used, and you need to make sure that they're kept very clearly separate so that there's no interference. Each frequency band needs to be in the correct lane, and that's where filters become critical. That's why, as you see in the latest iPhone 12, about 100 filters in an iPhone 12 in order to make sure that you get the best possible signal, which relates to the best possible consumer experience from 5G, from Wi-Fi, for most wideband in high data rates, very clear streaming video.

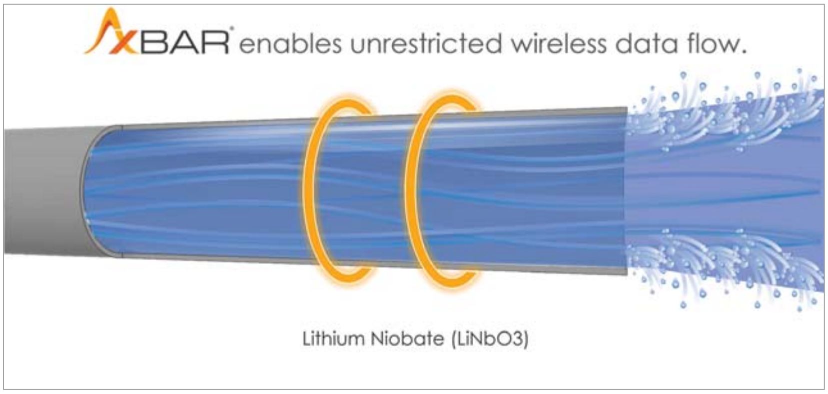
**Now, Mike, that brings to mind two issues. One is lean management and the other is the physical footprint of the solution. Are these all discrete filters or are they filter arrays? Because at some point, you're still soldering a lot of little teeny things to the board.**

Yes, exactly. That's why, because of this complexity, there is a very, very distinct move away from discrete filters to modules, so that the phone OEMs can buy an already pre-tested module that has all of those lanes very clearly defined within the module, which you can attach to the main PC board of a phone. With these modules, because of the nature of all these different frequency bands, it makes sense to break them up into big blocks.

You'd need a low-band module, which covers 600 MHz to about 1.2 GHz, a mid-band module, which covers that 2-GHz range, then a high-band module to cover 2 to 3 GHz. However, with all these new bands, there's going to be an ultra-high-band module, which covers what's called the sub-6-GHz range for 5G, millimeter-wave modules, which covers the 24- to 30-GHz range. So, breaking it down into building blocks makes sense, so you don't have to put an individual discrete filter on a PC board and test it and put another one on it, test it, because it becomes just an unmanageable complexity by doing it that way. So getting a pre-tested module makes a lot of sense.

**When you're talking about the RF pathway, there are so many choke points in so many areas. If the antenna isn't properly matched, you're going to lose a lot of power and you're going to lose a lot of performance. So it's not just that you have to have everything, it also has to be optimally matched to ensure the minimum loss.**

I'll give you two key points there. One is you could just keep adding antennas, but that becomes unmanageable very quickly. So what's happening is there is a big drive now and a need for sharing antennas. As I mentioned, if you've got a Wi-Fi module and a 5G module, they could share the same antenna by using what's called a multiplexer at the antenna. Right now, the latest iPhone 12




has eight antennas, for instance, using antenna sharing, but then you also have to be very clear.

You say, "How can I have the lowest loss possible?" Which means you need very good filters, with very steep skirts to prevent interference and degradation of your main signal. That's where our new XBAR filter technology comes into play, where you need these very wide bandwidths, at these high frequencies that have a minimal loss so that you receive signals as pure as possible. And you send signals with your amplifier as close as possible without draining your battery. Because what happens is if you add the loss on the signal, your power has to crank up, which drains your battery faster. And so, this idea that you brought up, a very, very low loss to main signal integrity, is critical. And that's where filters play an absolutely pivotal role.

**Do you have an end thought to round this all out and tie it with a new bow?**

We talked about how we're in the very early stages of these new wireless technologies. So 5G is in the first couple of years; what you see in the next two to three years is the spectrum will be allocated, then you have to deploy your infrastructure, so you're really going to start seeing the true benefits of 5G, of ultra-wideband in the next two to three years. That's when you're going to see the consumer experience really take off, and you'll start seeing all these new, very, very exciting applications, both in the smartphone, in devices, in IoT devices, in drones. You're just opening up a whole wealth of new applications.

It's critical, as I said, that we're going to need very, very high-performance wide-bandwidth low-loss filters. The next two to three years are going to be a really exciting time for wireless technologies and the new applications that 5G is going to generate. ■

## SPDT Switch Matrix Controls DC to 50 GHz

Mini-Circuits' model RC-8SPDT-50 is a millimeter-wave switch matrix for applications from dc to 50 GHz. It consists of eight single-pole/double-throw (SPDT) electromechanical switches in a fail-safe, reflective configuration; the switches are rated for two million switching operations. Operated by computer/software Ethernet or USB connection, the 50-Ω switch matrix has 5-ms typical switching speed and is ideal for test and measurement applications. Typical path loss is 0.4 dB or less to 50 GHz while typical VSWR is 1.35:1 or less to 50 GHz. Full-band isolation is typically 80 dB with isolation to 100 dB at 12 GHz and below.

**MINI-CIRCUITS,** https://www.minicircuits.com/WebStore/dashboard.html?model=RC-8SPDT-50

## SoC Brings 5G Capability to Smartphones


MediaTek's Dimensity 820 system-on-chip (SoC) is optimized for premium user experiences and provides ultra-fast 5G speeds for smartphones. The chip features four Arm Cortex-A76 cores (at 2.6 GHz) and four Arm Cortex-A55 cores (up to 2 GHz) within its eight-core CPU, which provides increased performance and responsiveness for AI, gaming, and photography applications. The Dimensity 820 also packs an Arm Mali G57 GPU with support for 120-Hz high frame-rate displays, a 5G NR (sub-6-GHz) modem, and a MediaTek APU. The SoC provides up to 16 GB of LPDDR4x RAM as well as UFS 2.2 storage, and can handle most cellular technologies, including 5G, GNSS, GSM, and more. It also includes onboard Wi-Fi capabilities, Bluetooth 5.1, and FM radio.

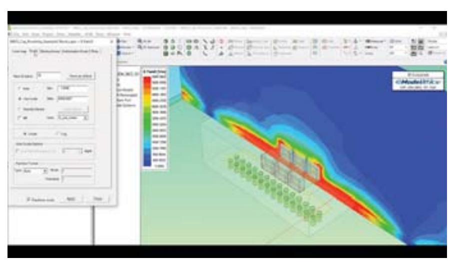
**MEDIATEK,** www.mediatek.com/products/smartphones/dimensity-820


## A Diverse Line of Reed Switches Encompasses Varied Applications

Teledyne Relays has rolled out four reed-relay product families, which provide a long life of up to 1 billion cycles and are ideal for high-reliability applications. The reed relays offer a compact and lightweight means of switching AC or DC signals. The contacts are hermetically sealed inside a glass envelope that protects them from corrosion. The relays are optimized for different demands, including single-in-line (SIL) and dual-in-line (DIL) packaged parts containing one or more reed switches and an electromagnet, encapsulated in thermoset plastic and packaged for easy solderability.

**TELEDYNE RELAYS,** www.teledynedefenseelectronics.com/relays/Pages/home.aspx

## Modeling Software Brings New Features for Ansys HFSS



Modelithics' COMPLETE+3D Library v20.1 for use with Ansys HFSS provides a large selection of highly scalable models for capacitor, inductor, and resistor families, along with a collection of geometry models for inductors and connectors. Version 20.1 provides five new part value, pad, and substrate scalable models, along with 93 full-wave 3D electromagnetic models. It also features models for Murata's GQM1555C capacitor series and LQP03HQ inductor series, and Vishay's MMA0204 resistor series. Moreover, the COMPLETE+3D Library v20.1 has updated models for AVX's 504L resistor series and Vishay's VJ0402 capacitor series and 3D EM models for Mini-Circuits filters and TDK inductors.

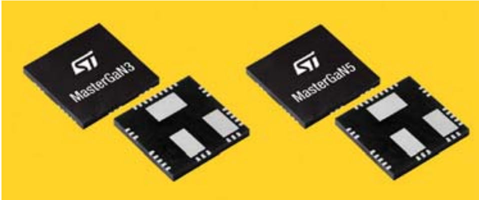
**MODELITHICS,** www.modelithics.com/model/models3d

## Voltage Variable Attenuator Adjusts 30 dB to 12 GHz


Mini-Circuits' model ZX73-123+ is a reflective voltage variable attenuator with 0-to-20-dB adjustment range from 6 to 12 GHz. Typical insertion loss is 0.8 dB at a 0-dB attenuation setting, with typical return loss of 15 dB. The 50-Ω variable attenuator operates with a single control voltage of +1 V dc or less and does not require an additional supply voltage. It handles input power as high as +20 dBm and has an operating temperature range of -55 to +85°C. The RoHS-compliant variable attenuator includes SMA female connectors and measures 1.20 × 1.00 × 0.38 in. (30.48 × 25.40 × 9.65 mm).

**MINI-CIRCUITS,** https://www.minicircuits.com/WebStore/dashboard.html?model=ZX73-123%2B

## Integrated Power Devices get Optimized for High-Voltage Applications




STMicroelectronics has released its MasterGaN3 and MasterGaN5 integrated power packages for applications up to 45 W and 150 W. The new devices give engineers the extra flexibility to choose the optimum gallium-nitride (GaN) device and driver solution when designing switched-mode power supplies, chargers, adapters, high-voltage power factor correction (PFC), and dc-dc converters. The MasterGaN3 device features an asymmetrical on-resistance of 225 mΩ and 450 mΩ, making this integrated power package ideal for soft-switching and active-rectification converters. The MasterGaN5 transistors provide 450-mΩ on-resistance and are excellent for use in topologies such as LLC resonant and active-clamp flyback. Both devices offer inputs compatible with logic signals from 3.3  to 15 V, which simplifies the connection of a host DSP, FPGA, or microcontroller, and external devices such as Hall sensors.

**STMICROELECTRONICS,** www.st.com/en/power-management/high-voltage-half-bridge-gate-drivers.html

## Waveguide Antennas Tackle mmWave 5G and High-Frequency Apps

Pasternack expanded its selection of mmWave waveguide antennas with 54 models to tackle the growing number of 5G and other high-frequency applications. The antennas cover broad operating-frequency ranges from 1.7 to 220 GHz, provide nominal gain ranging from 0 dBi to 40 dBi, and feature various waveguide sizes. They also can address point-to-point and point-to-multipoint wireless applications, including probe waveguide antennas to 170 GHz with 6.5 dBi of gain, dual-polarized waveguide antennas to 110 GHz with 13 to 20 dBi of gain, and corner reflector antennas with .02 m2-16,000 m2 radar cross-sections.

**PASTERNACK,** www.pasternack.com

## AI-Powered Chipsets Provide High Efficiency in a Small Form Factor

Maxim Integrated Products' MAX16602 AI core dual-output voltage regulator and the MAX20790 smart power-stage IC provide high efficiency for high-powered AI systems, edge computing, data centers, and more. The AI multi-phase chipset provides a 1% efficiency improvement compared to competitive solutions, enabling greater than 95% efficiency at 1.8-V output voltage and 200-A load conditions.


**MAXIM INTEGRATED PRODUCTS**, www.maximintegrated.com/en/products/power/switching-regulators/MAX16602.html

## Switcher ICs Target Next-Generation Mobile Charging Devices

Power Integrations announced its InnoSwitch 4-CZ series of high-frequency, zero-voltage-switching (ZVS) flyback switcher ICs designed for the next generation of mobile charging devices. The new ICs incorporate a 750-V primary switch using PowiGaN technology and a high-frequency, active-clamp flyback controller to facilitate a new class of ultra-compact chargers suitable for phones, tablets, and laptops. The series is outfitted with primary and secondary controllers, ClampZero interface, synchronous rectification, and safety-rated feedback in a single InSOP-24D package.

**POWER INTEGRATIONS,** www.power.com/products/innoswitch

## Low-Noise Amplifier Gains 6 to 18 GHz


Mini-Circuits' model PMA-183PLN+ is a miniature low-noise amplifier (LNA) with positive gain slope from 6 to 18 GHz. Ideal for communications and radar receivers, the 50-Ω pHEMT MMIC LNA features high typical directivity of 33 dB across the full bandwidth. It's supplied in a 16-lead MCLP housing to fit tight PCB layouts. Small-signal gain is typically 26.3 dB at 6 GHz, 27.5 dB at 15 GHz, and 29.7 dB at 18 GHz, while noise figure is typically 1.4 dB at 6 GHz, 1.2 dB at 15 GHz, and 1.3 dB at 18 GHz. The RoHS-compliant LNA typically draws 57.2 mA from +2.6 V dc. It provides typical output power at 1-dB compression of +9.8 dBm at 6 GHz and +10.2 dBm at 18 GHz.

**MINI-CIRCUITS,** https://www.minicircuits.com/WebStore/dashboard.html?model=PMA-183PLN%2B

## Updated Design Suite Improves Engineering Productivity


Version 15 (V15) of Cadence's AWR Design Environment includes AWR Microwave Office, AWR Visual System Simulator (VSS) and AXIEM and Analyst electromagnetic (EM) simulators. This release provides RF/microwave design solutions for monolithic microwave integrated circuit (MMIC)/RFIC, package/module, and PCB designs. V15 improves engineering productivity with analyses, faster and higher-capacity simulation technologies, design automation, and 5G New Radio (NR)-compliant test benches. The AWR Design Environment V15 increases throughput and productivity by reducing manual design tasks and supporting tool interoperability. It also supports power-amplifier (PA) and antenna/array designs, EM modeling, and RF/microwave integration across heterogeneous technologies.

**CADENCE DESIGN SYSTEMS**, www.awr.com/awr-software/products/awr-design-environment

## Industrial Ethernet Switches Step Up in IIoT Applications

Westermo's Lynx 5512 and RedFox 5528 industrial Ethernet switches were designed to meet the needs of future data-communication networks. By integrating hardware, software, and network design support, the new switch platforms provide advanced capabilities suitable for handling big data and the industrial Internet of Things.

**WESTERMO,** www.westermo.com/products/ethernet-switches/iec-61850-3

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(ISSN 0745-2993)
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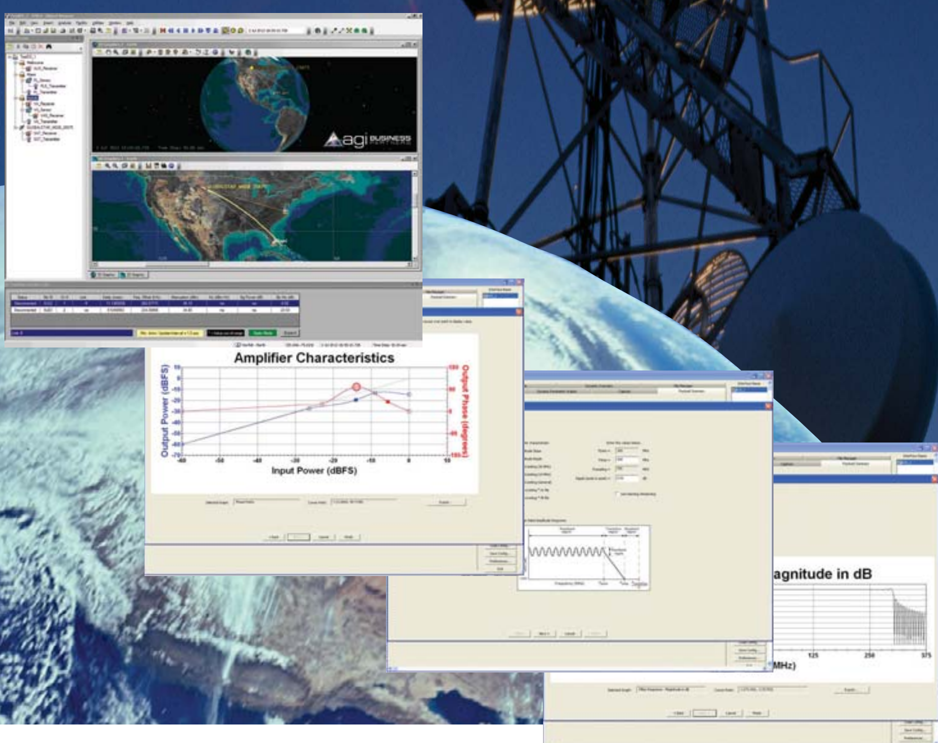


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