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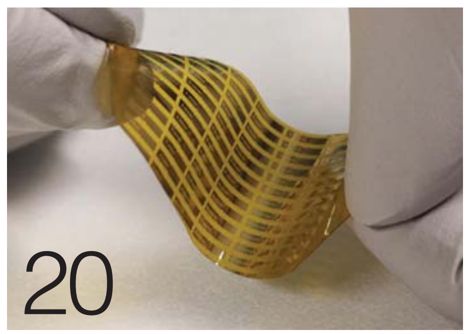

NEWS & COLUMNS

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Editorial

DAVID MALINIAK | Editor
dmaliniak@endeavorb2b.com

COVID-19 Forces New Supply-Chain Strategies

The pandemic's impact on manufacturing has made OEMs wary of offshore suppliers as supply chains suffer enormous damage.

If your organization has met with pandemic-related adversity regarding the manufacturing and supply-chain ecosystems, you're in the same boat with most others, says a new report on the state of global manufacturing. In its survey, 89% of respondents have seen a direct business impact because of COVID-19, manifesting in lower sales, increased costs for both materials and production, and delayed or canceled product launches.

According to the *2020 State of Manufacturing Report*, which contract-manufacturer Fictiv commissioned from Dimensional Research, only 17% of respondents gave high marks to their supply chain's performance over the last year. A majority are revisiting their reliance on China and looking to the U.S. as the next key manufacturing center.

The bright spot, however, is that nearly all (97%) say COVID-19 has created new opportunities, with most making digital transformation a high priority. As one might expect, supply-chain resilience is important to 99% of respondents, with 96% working to increase supply-chain agility.

Fictiv's report polled hundreds of senior manufacturing and supply-chain decision makers at companies producing medical, robotics, automotive, aerospace, and consumer-electronics products. It found that:

- Sales are down (44%), cost of materials and components increased (41%), and production times lengthened (41%).
- 36% had to lay off good employees.
- 24% have been unable to fill customer orders.

Many of the organizations surveyed are hoping that efforts toward digital transformation of their production and supply-chain processes, coupled with artificial-intelligence advances, will help them to begin turning things around:

- 87% have a high-priority digital transformation initiative.
- Reducing cost (46%), increasing supply-chain visibility (42%), and driving efficiencies (40%) are some of the top goals for these digital efforts.
- Yet, only 14% feel their digital-transformation initiatives are well-funded and 81% face difficulty finding necessary expertise.

In addition, 84% say they will be more cautious about offshoring now than in the past. But while many (73%) will minimize reliance on China, 74% will continue to source some parts from the region.

The upshot is that supply-chain managers are challenged at present, but they see opportunities to build more agile and resilient infrastructures that will help get them past the pandemic woes and positioned for rapid future growth. mw

Microwaves&RF AUGUST 2020

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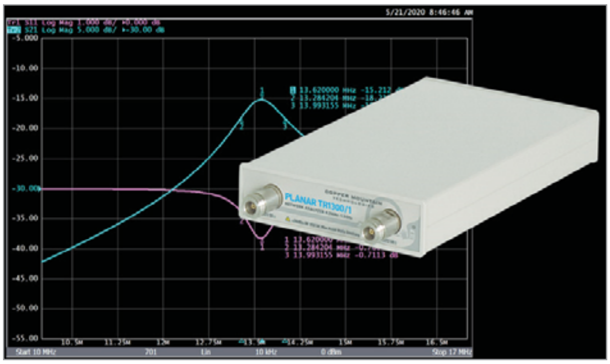
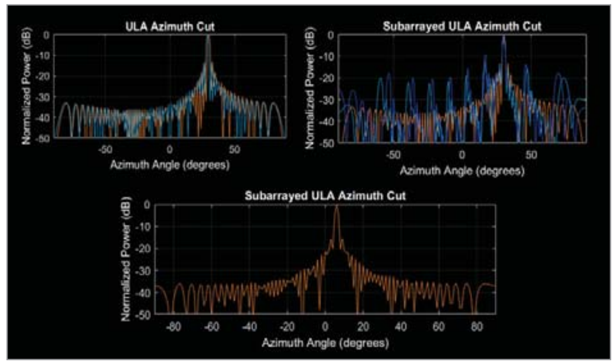


Determining Resonator Q Factor from Return-Loss Measurement Alone

Engineers often want to measure the Q factor of a resonator. But did you know you could affordably and accurately determine that Q factor from a return-loss measurement?

https://www.mwrf.com/technologies/test-measurement/article/21132616/determining-resonator-q-factor-from-returnloss-measurement-alone



Understanding LFOV Arrays and Wideband Scanning Arrays

This latest Algorithms to Antenna blog installment shows how to model a subarray network with different configurations for two specific applications: limited-field-of-view (LFOV) arrays and wideband arrays.

https://www.mwrf.com/technologies/systems/article/21136686/algorithms-to-antenna-understanding-lfov-arrays-and-wideband-scanning-arrays

Tubes: Luckily, They're Still Around

As Noah said to his family after dinner, "Those unicorn steaks were excellent!" Lou Frenzel weighs in on the venerable vacuum tube.

https://www.mwrf.com/line-of-sight/article/21133399/tubes-luckily-theyre-still-around

Remove Those Bottlenecks to Unleash the Promise of 5G

5G will enable new types of very high-performance applications, from gaming and AR/VR to machine learning, but they must be equipped with the right hardware to support required performance levels. The right storage solutions can help meet these demands.

https://www.mwrf.com/technologies/systems/article/21138090/remove-those-bottlenecks-to-unleash-the-promise-of-5g

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News

BlueNRG-2 Development Kit Unleashes Bluetooth 5.0

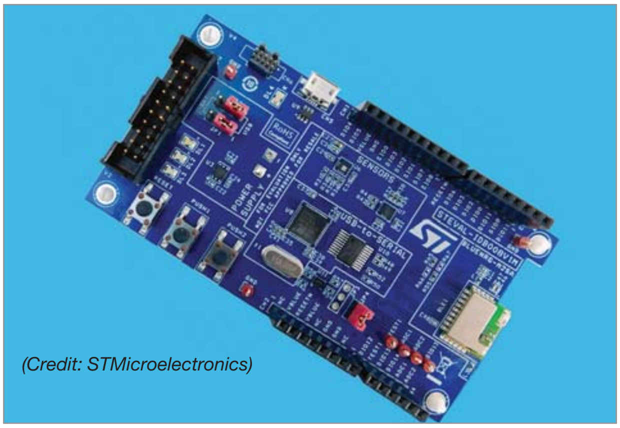
Platform jumpstarts new-application design with 2nd-generation BLE SoC for industrial and smart-building markets.

The STEVAL-IDB008V1M Bluetooth Low Energy 5.0 (BLE) evaluation platform from STMicroelectronics accelerates application development with modules featuring BlueNRG-2, the company's second-generation BLE System-on-Chip (SoC).

BlueNRG-2 supports the Bluetooth 5.0 certification, which allows enhanced security with LE Secure Connections, power-efficient privacy with Link Layer Privacy 1.2, and up to 2.6 times higher throughput with LE Data Length Extension. The SoC contains an Arm Cortex-M0 core operating at up to 32 MHz to handle the Bluetooth stack and application processing, and integrates new features including a 32-kHz ring oscillator, 24 kB of RAM and 256 kB of flash program memory. Reduced standby power is a further advantage, drawing just 0.9 µA in sleep mode with active Bluetooth stack and full RAM retention.

The BlueNRG-M2SA module combines in a compact 13.5-mm x 11.5-mm form factor the BlueNRG-2 SoC with an efficient ceramic antenna, RF balun circuit, and 32-kHz crystal oscillator and SMPS inductor to further reduce power consumption. Using this module greatly reduces engineering costs and enables designers to create wireless devices with minimal RF engineering expertise. BlueNRG-M2SA is qualified as a Bluetooth End Product, which relieves customers of additional testing to complete their own product qualification. The modules are also pre-certified according to US FCC, Canadian IC, European RED, Japan TYPE radio-equipment regulations and will also meet China SRCC requirements when those are finalized.

The STEVAL-IDB008V1M plug-and-play kit enables rapid evaluation and product development leveraging the BlueNRG-M2SA module. The board combines the BlueNRG-M2 module with sensors including a MEMS pressure and temperature sensor and motion sensors suitable for 9-axis sensor-fusion library. There is also a low-latency, low-power ADPCM codec, ready to use with BlueVoice middleware for voice-over-BLE streaming. Arduino R3 connectors are provided, which allow access to all the module's peripherals and enable users to further extend functionality by adding expansion shields. The associated development-software package, STSW-BLUENRG1-DK, contains a simple and intuitive BlueNRG-Navigator GUI that lets users bring their applications to life without an external programmer or hardware.

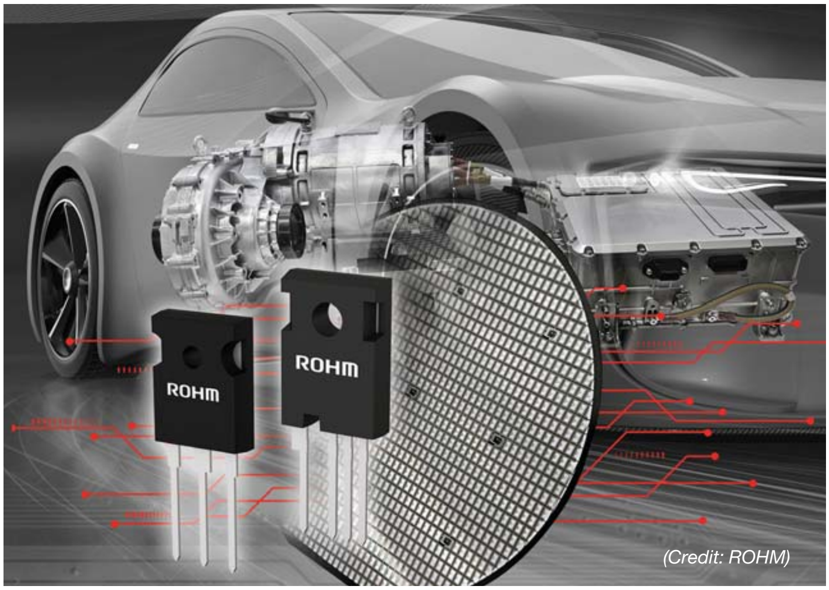


(Credit: STMicroelectronics)

The kit also simplifies integration of the BlueNRG-M2SA module with ST's STSW-BNRG-MESH software to explore emerging application opportunities in industrial and smart-building markets. The software implements the Bluetooth SIG Mesh Profile v1.0 to allow true two-way communication and range-extending mesh networks, with cyber-security leveraging integrated features of the BlueNRG-2 SoC.

With its operating temperature range of -40°C to 85°C and 5-dBm RF output power, the BlueNRG-M2SA module can be powered directly with a pair of AAA batteries or any power source from 1.7 to 3.6 V. The module is well-suited for industrial applications.

The STEVAL-IDB008V1M evaluation kit is available now.



(Credit: ROHM)

4th-GENERATION SiC MOSFETs
Boast Industry's Lowest On-Resistance

IN RECENT YEARS, the proliferation of next-generation electric vehicles (xEVs) has hastened the development of smaller, lighter, and more efficient electrical systems. Improving efficiency while decreasing the size of the drive system's main inverter remains among the most important challenges, requiring further advancements in power devices. Onboard vehicle batteries are gaining in capacity so as to improve cruising range, while also moving to higher voltages (800 V) to meet demands for shorter charging times.

For power semiconductors, there is often a tradeoff between lower on-resistance and short-circuit withstand time, which is required to strike a balance for achieving lower power losses in SiC MOSFETs. In its new 4th-generation 1200-V, SiC power MOSFETs, ROHM was able to successfully improve this tradeoff relationship and reduce on-resistance per unit area by 40% over conventional products without sacrificing short-circuit withstand time by further improving an original double-trench structure. In addition, significant reduction in the devices' parasitic capacitance (which is a problem during switching) makes it possible to achieve 50% lower switching loss over the company's previous generation of SiC MOSFETs.

As a result, the new SiC MOSFETs can deliver low on-resistance with high-speed switching performance, contributing to greater miniaturization and lower power consumption in a variety of applications, including automotive traction inverters and switching power supplies.

In 2015, ROHM began mass production of the industry-first trench-type SiC MOSFETs utilizing an original structure. In these new devices, the company has reduced on-resistance by 40% compared to conventional products without sacrificing short-circuit withstand time by further improving its original double trench structure.

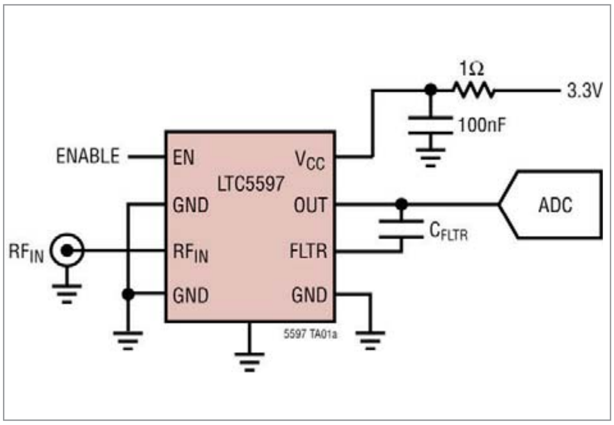
Generally, lower on-resistances and larger currents tend to increase the various parasitic capacitances in MOSFETs, which can inhibit the inherent high-speed switching characteristics of SiC. However, ROHM was able to achieve 50% lower switching loss over conventional products by significantly reducing the gate-drain capacitance (Cgd).

Bare chip samples are available now with discrete packages to be offered in the future. ■

LINEAR-IN-dB RMS POWER DETECTOR Spans 100 MHz to 70 GHz

THE RF SIGNAL CHAIN is defined by power rather than voltage or current. Providing root-mean-square (RMS) measurement of this power over a wide dynamic range is critical circuit and system requirement. Fortunately, today's ICs feature frequency range and performance capabilities that continue to extend to meet the needs of the ever-growing electromagnetic spectrum of interest.

Among the latest offerings is the LTC5597 RMS Power Detector from Analog Devices. As with so many tightly focused RF parts, it implements one primary function and does it well. This 8-lead device in a diminutive 2- × 2-mm package *(Fig. 1)* boasts a fully specified operating span of 100 MHz to 70 GHz with a 35-db "linear" dynamic range. Its 28.5-mV/dB logarithmic slope has a typical error of less than ±1 dB. Among its other specifications are ±2-dB flat response from 100 MHz to 60 GHz.



1. The functionality and pinout of the LTC5597 are simple, which is commensurate with the role it plays in the RF signal chain.

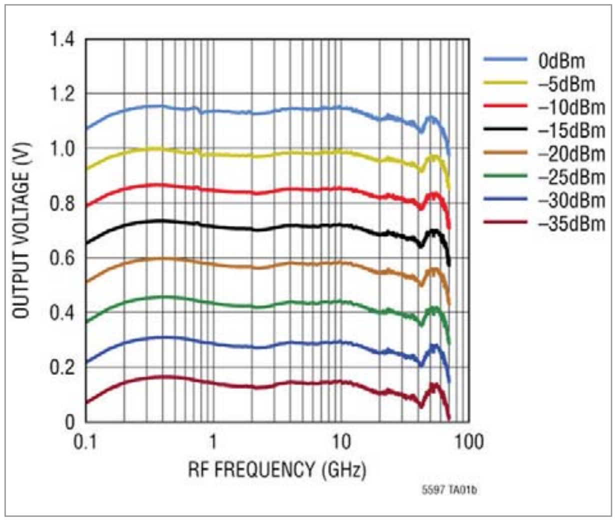
The device is well-suited for measurement of waveforms with crest factor (CF) as high as 12 dB, including waveforms that exhibit a significant variation of the crest factor during measurement—an increasingly frequent scenario in today's advanced-modulation environments. Such specifications and performance make it a good option for a wide range of applications, including but not limited to point-to-point microwave links, satellite communication links, instrumentation and measurement equipment, military radios, 5G/LTE/Wi-Fi wireless networks, RMS power measurement, and transmit power/receive gain control.

The averaging bandwidth can be externally adjusted using a capacitor to achieve higher accuracy along with lower output ripple. The 3.3 V draws just 33 mA (typical) while an enable pin switches the device between active-measurement mode and a low power shutdown mode.

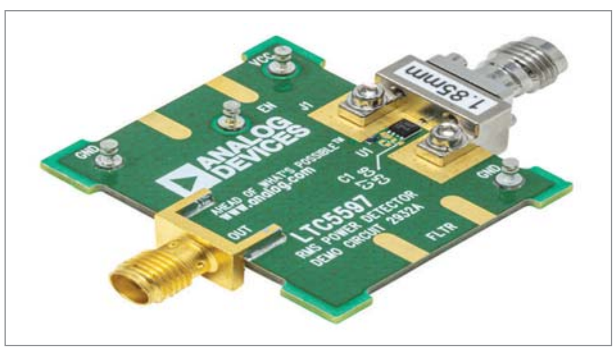
As with most RF parts, designers prefer an abundance of charts and graphs on the datasheet. The comprehensive 22-page datasheet includes over two dozen graphs *(Figure 2 is one example)* plus tables showing performance, errors, and deviations across a wide array of factors including voltage, input power, temperature, and more.

Designs also welcome (and expect) evaluation boards for these devices, even though their basic interconnection schematic is quite simple. The DC2932A ($600) provides a PCB layout that employs the recommended microstrip transmission-line structure and endpoint transitions *(Fig. 3)*. (Note that the input impedance to LTC5597 is internally matched to 50 Ω.) Support for the demonstration circuit includes schematic, design, and integration files, and a user guide.

The LTC5597 is offered fully specified over the –40 to +105°C and –40 to +125°C ranges; prices begin at $48.95 (1000+ pieces). ■



2. Among the many performance graphs on the datasheet is this one quantifying the tight "linearity" of the output voltage versus input frequency over a wide range of power levels.



3. The DC2932A evaluation board/demonstration circuit, which enables designers to exercise the LTC5597 RMS Power Detector IC, comes with full schematic, layout, and user guide.

DAVID MALINIAK | Senior Editor

Anritsu's 5G NR Mobile Test Platform Makes Grade in Protocol Conformance Test

Anritsu validations included tests for non-standalone (NSA) mode, standalone (SA) mode, and frequency bands covering time-division duplex (TDD) and frequency-division duplex (FDD).

According to Anritsu, the PTCRB (PCS Type Certification Review Board) Validation Group (PVG) has agreed to the highest number of 5G New Radio (NR) Protocol Conformance tests on the company's ME7834NR 5G NR mobile device test platform at its PVG#89 meeting in May. These tests were subsequently approved during the PTCRB#104 meeting in June.

Anritsu validations included tests for non-standalone (NSA) mode, standalone (SA) mode, and frequency bands covering time-division duplex (TDD) and frequency-division duplex (FDD). As a result, the Anritsu ME7834NR maintains its high standing among the industry's leading protocol conformance-test platforms. Thanks to its broad test coverage, the platform enables chipset suppliers, device manufacturers, and test houses to accelerate the certification and introduction of new 5G devices and services.

The conformance tests are defined by 3GPP in TS 38.523 and have been validated on multiple sub-6-GHz Frequency Range 1 (FR1), and millimeter-wave (mmWave) Frequency Range 2 (FR2) frequency bands. The ME7834NR mobile test platform is registered with the Global Certification Forum (GCF) and PCS Type Certification Review Board (PTCRB) as Test Platform (TP) 251.

The ME7834NR 5G NR mobile device test platform performs 3GPP-based protocol conformance test (PCT) and carrier acceptance testing (CAT) of mobile devices incorporating multiple radio access technologies (RATs). It supports 5G NR in both SA and NSA modes, in addition to LTE, LTE-Advanced (LTE-A), LTE-A Pro, and W-CDMA. When combined with Anritsu's new OTA MA8171A RF chamber and RF converters, the ME7834NR covers the sub-6-GHz and mmWave 5G frequency bands. mw

(Credit: Anritsu)

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RICHARD EDGAR | Senior Director of Product Management, Imagination Technologies

(Credit: Busakorn Pongparnit, Dreamstime)

Wi-Fi 6 is Set to Change the Future of IoT—Here's Why

Wi-Fi is more than an internet gateway for phones, tablets, and computers. It can be used to connect virtually every item imaginable. And with Wi-Fi 6, the true potential of the IoT can be fully realized.

Wi-Fi is easily one of the most widespread technologies ever invented, allowing for unprecedented connectivity across a near endless list of devices. With more than 450 million Wi-Fi hotspots expected to be deployed in 2020 and an installed base of more than 13 billion Wi-Fi devices, the technology is a global success story.

Its potential to transform industries is even greater than most realize. Wi-Fi is more than an internet gateway for phones, tablets and computers—it can be used to connect virtually every item imaginable. From household appliances to traffic signals and beyond, Wi-Fi is also building a path to the Internet of Things (IoT), which has evolved to allow for more robust applications. IoT is now capable of monitoring equipment to search for indications of failure. It can analyze the temperature of commercial refrigerators to prevent food from spoiling at restaurants and grocery stores. And it can keep a close eye on carbon-monoxide levels to ensure we aren't at risk for CO poisoning.

These are all vital features that will shape the future of IoT, with many more benefits sure to follow. For example, HVAC units could be equipped with sensors to alert both commercial and residential users of problems that would otherwise go unnoticed. A good example involves what happens if the air-conditioning unit leaks refrigerant. More often than not, users will be unaware until the HVAC stops blowing cold air.

Similarly, if the pilot light goes out, users may not even know until they need heat. When equipped with the right sensors, these and other issues can be detected as soon as they materialize, paving the way for faster repairs.

This same technology can be applied to virtually any item: water heaters, pipes, gas lines, power lines—you name it and IoT-enabled sensors can be there to sound the alarm when something goes wrong. Most of those sensors will be battery-powered, though, which can be challenging when they're attached to appliances that last for many years. Users can't be expected to constantly monitor the battery life of their sensors, so they must be energy-efficient. With Wi-Fi 6 (the new IEEE 802.11ax standard), this is no longer a concern.

Wi-Fi 6 reinforces our belief that the technology is the premier option for IoT connectivity. Featuring data rates up to 10 Gb/s with eight antennas, 160-MHz bandwidth, and 1024 QAM, the technology can serve power-hungry devices with large batteries, such as mobile phones, tablets, and laptops. It's fast and reliable without draining too much power. But it can also serve reduced spec devices, such as those reaching 230 Mb/s with only one antenna, 40 MHz, and 256 QAM. This allows for smaller, lower-powered devices to also enjoy the benefits of Wi-Fi 6.

And by operating at 5 GHz, Wi-Fi 6 avoids the highly congested 2.4-GHz frequency band. It was designed from the ground up to improve data throughput, increase robustness, and reduce power consumption without hindering performance.

CONSISTENT THROUGHPUT IS CRUCIAL

A lot of hype has surrounded Basic Service Set (BSS) Coloring, and for good reason. This feature can alleviate the challenge of delivering consistent throughput in areas where there are multiple access points. Once we get back to having conferences, for example, large crowds of people may be trying to access the same network. This is very likely to reduce internet speeds—or worse, prevent users from connecting altogether—as data from different access points overlap, causing contention and interference.

A lot of hype has surrounded Basic Service Set (BSS) Coloring, and for good reason. This feature can alleviate the challenge of delivering consistent throughput in areas where there are multiple access points.

Wi-Fi 6 uses the new BSS Coloring feature to colorize data from each access point, allowing clients to identify which one is transmitting. This results in improved network performance and much happier users.

NO NEED TO WAKE UP EARLY

Consumer devices have relied on "standby" and "sleep" functions to reduce battery consumption when not in use, and sensors should be no different. Wi-Fi 6 introduces a new feature called Target Wait Time (TWT) that allows access points to negotiate with attached devices to agree when they should wake up to transmit data.

As a result, devices can sit quietly in a deep sleep for long periods of time, significantly reducing current consumption, which in turn increases battery life. This could extend the battery's lifespan to multiple years, allowing sensors to collect data in the field for much longer periods.

MORE FEATURES FOR SUPERIOR PERFORMANCE

Wi-Fi 6 also comes equipped with orthogonal frequency-division multiple access (OFDMA), which improves performance in high-density environments. It enables bandwidth within channels to be segmented, enabling multiple devices to receive data in the same time frame.

Like other Wi-Fi 6 features, OFDMA reduces power consumption. The benefits here are twofold. With lower power consumption, developers can create smaller sensors with even smaller batteries. Alternatively, they could simply choose to keep the battery as is while benefiting from the reduction in power consumption, improving the sensor's longevity. As IoT expands and more sensors are deployed (think automotive and other widespread applications), the tech would be impossible to maintain if the batteries needed to be changed every month.

YOUR FUTURE, MORE CONNECTED THAN EVER

These are just some of the reasons why we're convinced that Wi-Fi 6 will be the future of IoT device connectivity. By improving both energy efficiency and data throughput, it will be imperative to the industry—and a key technology to watch in 2020. mw

REFERENCE

"Imagination marks 20 years of the Wi-Fi Alliance," *https://www.imgtec.com/blog/imagination-marks-20-years-of-the-wi-fi-alliance/*

- Amplifiers - Solid State
- Attenuators - Variable/ Programmable
- Bi-Phase Modulators
- Couplers (Quadrature, 180, Directional)
- Detectors - RF / Microwave
- DLVAs, ERDLVAs & SDLVAs
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- Frequency Discriminators & IFM
- Frequency Synthesizers
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DTA-100M40G-30-CD-1

DTA-200M18G-100-CD-EXT

DTA-1G18G-60-7-CD-1-HERM

DTA-2G18G-60-12-CD-1-20DBM-TS

PMI Model No.	Frequency Range (GHz)	Attenuation Range (dB)	Attenuation Flatness (dB)	Switching Time (Max)	Insertion Loss (dB)	Control / Size (Inches) / Connectors
Digitally Controlled Attenuators (https://www.pmi-rf.com/categories/digitally-controlled-attenuators)						
DTA-30M6G-60-CD-1 https://www.pmi-rf.com/product-details/dta-30m6g-60-cd-1-	30 MHz - 6	60	10 dB: ±1.0 20 dB: ±1.5 40 dB: ±3.0 60 dB: ±5.0	50 µs	4 dB Max	8-BIT TTL 2.0" x 1.8" x 0.5" SMA (F)
DTA-100M40G-30-CD-1 https://www.pmi-rf.com/product-details/dta-100m40g-30-cd-1-	0.1 - 40	30	10 dB: ±0.95 20 dB: ±1.47 30 dB: ±2.13	On: 1 µs Off: 0.5 µs	5 dB Max to 20 GHz, 8 dB Max to 40 GHz	5-BIT TTL 2.0" x 1.8" x 0.5" 2.92mm (F)
DTA-200M18G-100-CD-EXT https://www.pmi-rf.com/product-details/dta-200m18g-100-cd-ext	0.2 - 18	100	20 dB: ±1.0 40 dB: ±1.25 60 dB: ±1.5 80 dB: ±2.0 100 dB: ±3.0	On: 1 µs Off: 0.5 µs	12 dB Max	8-BIT TTL 4.0" x 1.8" x 0.5" SMA (F)
DTA-1G18G-60-7-CD-1-HERM https://www.pmi-rf.com/product-details/dta-1g18g-60-7-cd-1-herm	1 - 18	60	20 dB: ±1.0 40 dB: ±1.25 60 dB: ±3.0	On: 1 µs Off: 0.5 µs	5 dB Max, 4.8 dB Typ	7-BIT TTL 2.0" x 2.79" x 0.66" SMA (F)
DTA-2G18G-60-12-CD-1-20DBM-TS https://www.pmi-rf.com/product-details/dta-2g18g-60-12-cd-1-20dbm-ts	2 - 18	60	20 dB: ±1.0 40 dB: ±1.25 60 dB: ±3.0	On: 1 µs Off: 0.5 µs	4.8 dB Max	12-BIT TTL 2.0" x 1.8" x 0.5" SMA (F)
DTA-18G40G-50-CD-1 https://www.pmi-rf.com/product-details/dta-18g40g-50-cd-1	18 - 40	50	±1.5	On: 1 µs Off: 0.5 µs	8.5 dB Typ	10-BIT TTL 2.0" x 1.8" x 0.5" 2.92mm (F)
Analog Controlled Attenuators (https://www.pmi-rf.com/categories/analog-controlled-attenuators)						
PVVAN-0R4G6G-40-MP-1 https://www.pmi-rf.com/product-details/pvvan-0r4g6g-40-mp-1-	0.4 - 6	40	12 dB: ±0.23 24 dB: ±0.15 36 dB: ±0.54 40 dB: ±0.68	5 µs Typ, 10 µs	4.0 dB Max, 2.8 dB Typ	0 to +10 VDC (Linearized) 2.0" x 1.81" x 0.88" SMA (F)
PVA-500M18G-60-SFF https://www.pmi-rf.com/product-details/pva-500m18g-60-sff-	0.5 - 18	60	0-10 dB: ±1.0 10-20 dB: ±1.5 20-40 dB: ±2.0 40-60 dB: ±2.5	3 µs	4.5 dB Max, 0.5-12 GHz 5.8 dB Max, 12-18 GHz	10 dB / Volt 2.0" x 1.8" x 0.5" SMA (M/F)
PVVAN-2040-60-MP https://www.pmi-rf.com/product-details/pvvan-2040-60-mp-	2 - 4	60	10 dB: ±0.45 20 dB: ±0.80 40 dB: ±1.50 60 dB: ±1.60	500 ns	2 dB Max	10 dB / Volt 2.0" x 1.8" x 0.5" SMA (F)
PVVAN-8018-60-MP https://www.pmi-rf.com/product-details/pvvan-8018-60-mp-	8 - 18	60	10 dB: ±0.80 20 dB: ±1.10 40 dB: ±1.50 60 dB: ±1.60	500 ns	3.7 dB Max	10 dB / Volt 2.0" x 1.8" x 0.5" SMA (F)

DTA-18G40G-50-CD-1

PVVAN-0R4G6G-40-MP-1

PVA-500M18G-60-SFF

PVVAN-2040-60-MP

PVVAN-8018-60-MP

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BILL SCHWEBER | Contributing Editor

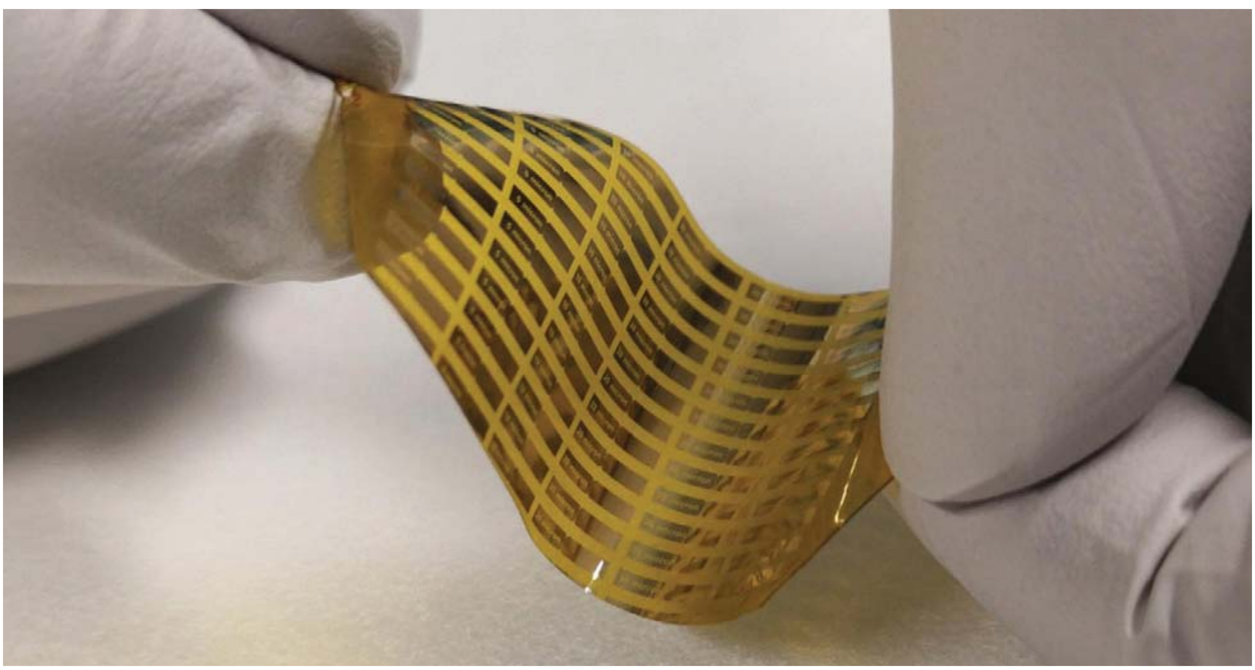
Picosecond Switching, Plasma Create All-Electronic Terahertz Pulses

Researchers developed relatively powerful terahertz pulses in a continuous stream by using large-magnitude picosecond pulses in a plasma-driven, chip-based arrangement.

The quest for sources of terahertz-band energy using lasers, electro-optics, solid-state devices, and anything else imaginable continues—no matter how "far out"—as this relatively open frontier of electromagnetic spectrum beckons with its enormous bandwidth, potential for extreme data rates, and other interesting possibilities (such as the ability to "see" below the skin or through walls). Another recent project uses ultra-fast, wide-swing switching with a relatively simple arrangement compared to some of the other approaches.

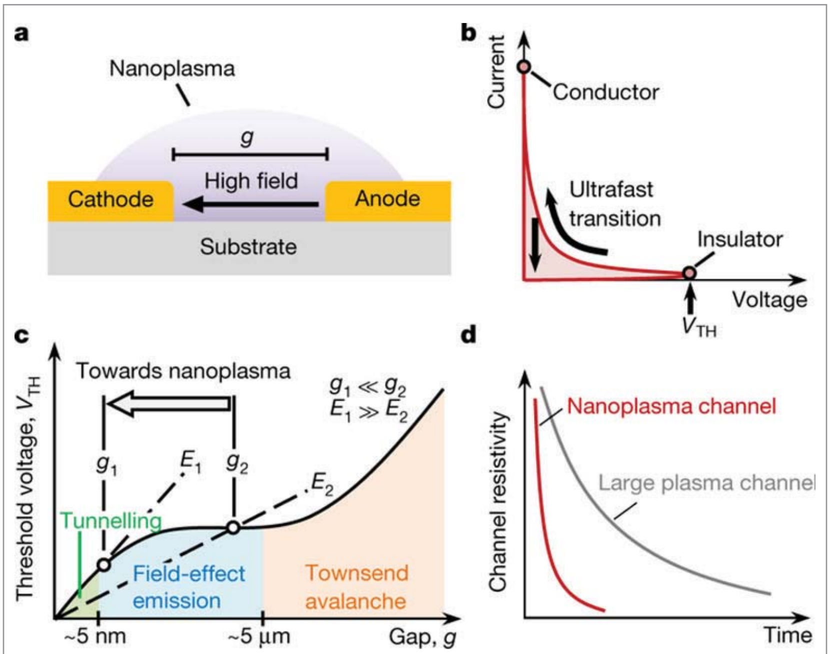
Researchers in the Power and Wide-band-gap Electronics Research Laboratory (POWERlab) at Ecole polytechnique fédérale de Lausanne (EPFL, Lausanne, Switzerland) have devised, built, and evaluated a chip-based nanodevice that can generate relatively high-power THz signals using picosecond switching. The core of this generator consists of two metal plates set 20 nm apart *(Fig. 1)*.

1. The concept of a nanoplasma switch: Schematic of the structure of a nanoplasma switch with gap length g (a). The switch is normally OFF and becomes ON at the threshold voltage $V = V_{TH}$ by electron transport in the high-electric-field region. Current–voltage characteristics of a nanoplasma switch (b). The transition from the insulating phase to the conducting phase is ultra-fast, while the conducting-to-insulating transition is controlled by the external circuit. Threshold voltage V_{TH} versus gap distance, showing a much



larger electric field (E) for devices with nanoscale gaps (c). The higher electric field in a shorter gap distance results in a much faster electron transport for nanoplasma devices (d). (Source: EPFL)

An applied voltage causes electrons to surge toward one of the plates, where they form a nanoplasma. Once the voltage reaches a threshold, the electrons are emitted almost instantly to the second plate. The rapid movement enabled by the fast switching creates a high-intensity pulse that produces high-frequency waves *(Fig. 2)*. Such fast switching and wide voltage slewing of the "spark" is critical. In this arrangement, the voltage transitions from 10 V (or less) to 100 V in the 5- to 10-ps range, and can do so at a rate up to 50 MHz.



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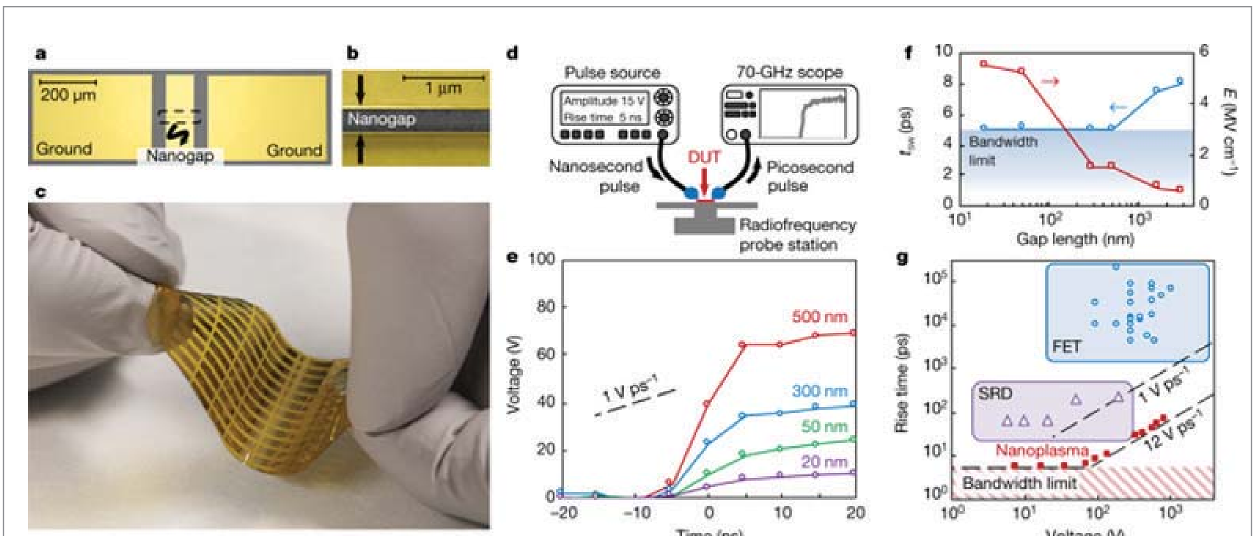


2.

2. Implementation of nanoplasma switches: Micrograph of a nanoplasma switch integrated with radiofrequency pads (a). A scanning electron microscope image of the nanogap (b). Fabricated devices on Kapton showing their possible integration in flexible substrates (c). Schematic of the experimental setup for switching characterization of the nanoplasma devices (d). Measured switching waveforms showing 6-ps rise time of high-amplitude signals (e). Measured switching time (t_{SW}, blue) together with the estimate dielectric field in the nanogap (E, red) (f). After de-embedding the effect of cable and radio-frequency probe, a 5-ps rise time was obtained. Benchmark of the rise time/switching voltage of nanoplasma versus other state-of-the-art electric devices (g). (Source: EPFL)

The researchers note that the switching frequency of this experiment was limited by their solid-state pulse generator. They demonstrated a 20-MHz switching frequency at 390 V together with an ultra-fast recombination time of less than 20 ns, which enabled further increase in the switching frequency up to 50 MHz.

By integrating these devices with a dipole antenna for signal emission, high-power terahertz signals with a power–frequency (Pf^2) product of 600 mW-THz^2 were emitted, with an average peak power of 50 W at 10^9 GHz

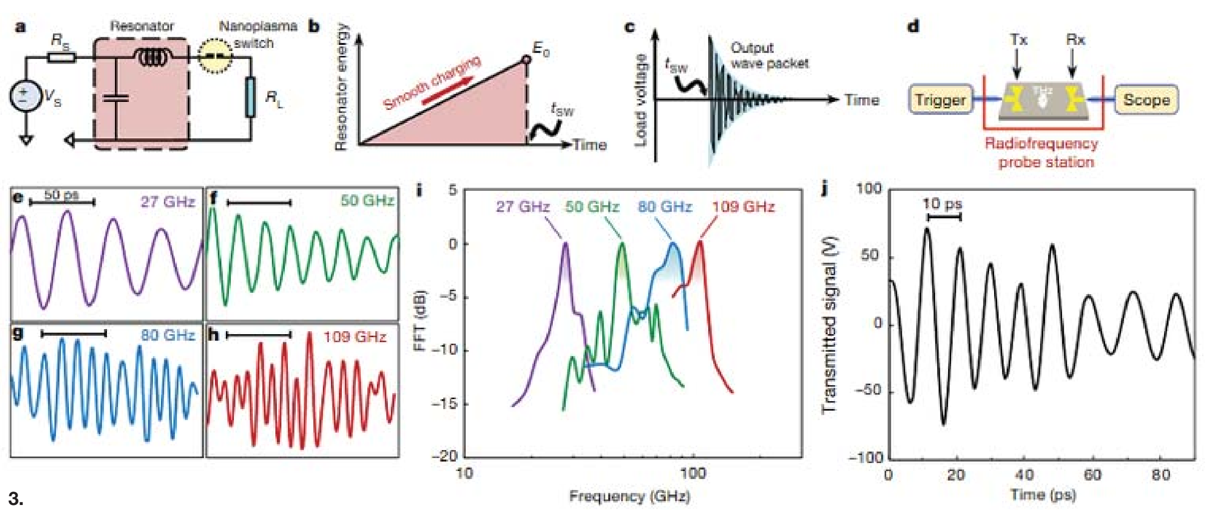
“Normally, it’s impossible to achieve high values for both variables [high energy and high frequency]. High-frequency semiconductor devices are nanoscale in size. They can only cope with a few volts before breaking out. High-power devices, meanwhile, are too big and slow to generate terahertz waves. Our solution was to revisit the old field of plasma with state-of-the-art nanoscale fabrication techniques to propose a new device to get around those constraints.”

(Fig. 3). The team maintains that their ultra-fast switching speed of better than 10 V per picosecond is about two orders of magnitude larger than that of field-effect transistors and more than 10X faster than that of conventional solid-state switches.

Team leader Prof. Elison Matioli noted that “normally, it’s impossible to achieve high values for both variables [high energy and high frequency]. High-frequency semiconductor devices are nanoscale in size. They can only cope with a few volts before breaking out. High-power devices, meanwhile, are too big and slow to generate terahertz waves. Our solution was to revisit the old field of plasma with state-of-the-art nanoscale fabrication techniques to propose a new device to get around those constraints.” He added that “the new device pushes all the variables to the extreme—high-frequency, high-power, and nanoscale aren’t terms you’d normally hear in the same sentence.”

This work was partially supported by the Swiss Office of Energy and the Swiss National Science Foundation (SNSF). Full details are in their paper “Nanoplasma-enabled picosecond switches for ultrafast electronics” published in *Nature* (with over one hundred references).

3. Nanoplasma-based millimeter-wave/terahertz source: Circuit diagram of millimeter-wave/terahertz source realized by a nanoplasma switch (a). R_S is the series resistance of the voltage source V_S. The voltage source V_S smoothly charges a fast resonator, which is excited at $V = V_{TH}$ when the nanoplasma switch turns ON with picosecond transition time (b). Illustration of the generated millimeter-wave/terahertz pulse at $t = t_{SW}$ (c). Schematic of the experimental setup; the terahertz pulse is emitted by a transmitter antenna (Tx) connected to the nanoplasma switch and the received wave (Rx) is measured by an ultrahigh-frequency oscilloscope (d). Measured waveforms with bowtie antennas with different sizes (the transmitter and receiver antennas have the same size) resulting in central frequencies of 27 GHz (e), 50 GHz (f), 80 GHz (g) and 109 GHz (h). Frequency spectrum of the received signals for four different antenna sizes showing the flexibility of the method in generating high-frequency signals at different frequencies (i). Calculated radiated signal from the transmitter antenna, based on the measured S_{21} after de-embedding the effect of the cables and radio-frequency probe, showing a high average peak power of 50 W at 10^9 GHz (j). (Source: EPFL) mw



3.

ALIX PAULTRE | Contributing Editor

Expanded Device Certification Process to Accelerate LoRa Market Growth

Offering a path for non-LoRa Alliance members to obtain LoRaWAN device certification, the certification program includes full protocol testing with interoperability and RF performance.

Recently the LoRa Alliance, an international association backing the open LoRaWAN standard for Internet of Things (IoT) low-power wide-area networks (LPWANs), announced its Certification Affiliate option for certifying devices. Offering a path for non-LoRa Alliance members to obtain LoRaWAN device certification. The LoRaWAN certification program includes full protocol testing with interoperability and RF performance.

The Certification Affiliate program allows any device manufacturer to certify its products, ensuring they meet end-user requirements for dependability, interoperability and security as defined by the LoRaWAN standard. Historically, companies were required to be a member of the LoRa Alliance to certify their devices. However, as certification is key to global adoption, the LoRa Alliance began to offer this option. The organization still encourages companies to become members of the LoRa Alliance, as the cost to certify is lower and there are many more benefits for member companies.

DEREK WALLACE, LoRa ALLIANCE MARKETING VICE PRESIDENT

We recently had the opportunity to talk about the LoRa Alliance and the expansion of the infrastructure and community with Derek Wallace, the

> "Our LoRaWAN certification test tool, the LCTT, is really important, and is the first of the two examples. This is a software package that, until two weeks ago, only member companies could obtain access to. They download this tool to their bench, and it runs a whole suite of tests against the LoRaWAN specification." *(Fig. 1)*

LoRa Alliance's Marketing Vice President. We went over the environment and how this initiative impacts the design and development community.

Derek: "Okay. So the growth of LoRa Alliance over the last couple of years has been tremendous, especially as IoT really is beginning to mature. We currently have about 245 LoRaWAN-certified devices from different manufacturers out there in the world. It's very important to have certified devices, as they are the best bet for anyone utilizing LoRaWAN. In addition, having certified devices means that those devices will be shaped according to the inherence security that's built into the LoRaWAN specification.

"Our LoRaWAN certification test tool, the LCTT, is really important, and is the first of the two examples. This is a software package that, until two weeks ago, only member companies could obtain access to. They download this tool to their bench, and it runs a whole suite of tests against the LoRaWAN specification *(Fig. 1)*.

1. The LoRaWAN certification test tool runs a whole suite of tests against the LoRaWAN specification.

"This allows developers to complete the test in their own laboratories utilizing this tool, so they will have a much higher degree of certainty when they send those devices to an official test house to become LoRaWAN certified. This will save companies a lot of money, time and resources as they go through an official certification program with the test house."

MEMBER EXPERIENCES

Derek: "I was on the phone with a member company called Cavagna Group out of Italy a few weeks ago, and their experience is exactly why we developed the tool. They gushed about how well and how quickly and how much more easily it was for them to go through the certification process because they utilized the tool. They performed all the tests. They knew that their device was going to pass certification before they sent it to the lab. They passed certification the very first time. The length of time in the lab for the certification was significantly reduced.

"They felt that they saved a lot of money, a lot of time and resources they could then re-allocate to different parts of their IoT business. Thankfully, they will be doing a 'did you know' video for us as part of our series talking about their experience with the LCTT. So with more and more companies having this, shortening the time, cost, and resources to obtain certification of devices, that is going to help increase the number of certified devices that are out there in the world."

THE CERTIFICATION AFFILIATE PROGRAM

Derek: "The second of the impacts for why we'll see a lot more certified devices out there in the world is the certification affiliate program that we have launched as an Alliance and we announced this two weeks ago. Now I do have more slides on this lower in the deck, but what I'll say is that as a highlight is for whatever reason, some of it's IP, some of it's just company policy. Some companies are just simply not able to join the LoRa Alliance. However, they are still very involved in LoRaWAN and they manufacture devices. These are some very large companies and also small companies.

"We have three committees within the LoRa Alliance. There's a technical committee responsible for determining the LoRaWAN specification. The protocol covers how it works, how it's interoperable, the security parameters around it, and the feature functionalities of the specifications. The certification committee, which also created the certification affiliate program that I talked about. Then there's the marketing committee, which is all about promoting awareness, adoption and supporting members and their efforts in their LoRaWAN business."

LoRaWAN APPLICATION EXAMPLES

Derek: "We have lots of use cases. For example, Chevron, one of our newer members, has been working with LoRaWAN for a while, and towards the end of last year announced a use case for their oil well heads in the San Joaquin Valley. They have 18,000 wells and devices in the field to operate and maintain, and many of the data points used to manage and maintain the rigs were still manually collected *(Fig. 2)*.

"Recently the company added 'smart lids,' in the manner of what you might find at an amusement park or in a smart city to monitor trash. The smart lids take level readings from the wells, and transmits the data over LoRaWAN using nodes with 10-year batteries that can transmit over 10 miles in ideal conditions. Chevron is now investigating the use of LoRaWAN to monitor temperature, pressure, and vibration, as well as soil samples."


2. Chevron has 18,000 wells and devices in the field to operate and maintain.

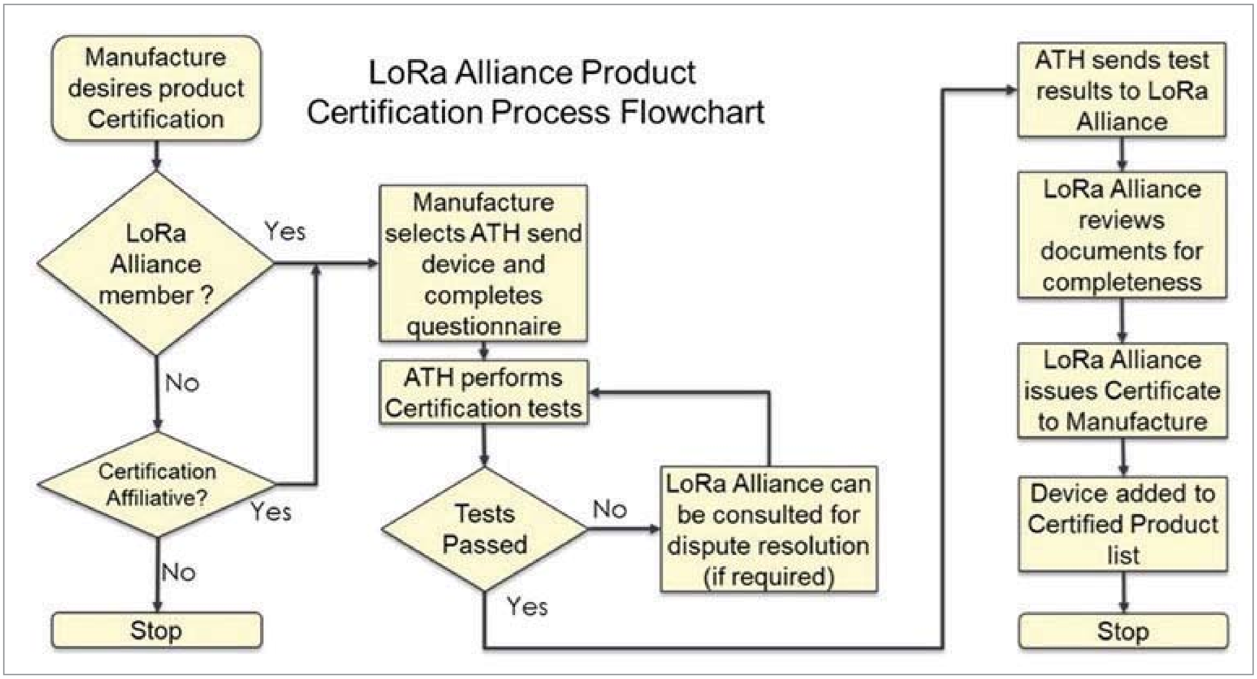
THE SKY'S THE LIMIT

Derek: "Then we have new companies like Fleet Space and Lacuna Space *(Fig. 3)*. They are using LoRaWAN via a satellite for back haul in remote places, where you just are not going to get cellular coverage of any kind, and the infrastructure is nonexistent as well. So, you can't use other types of communication to get up to the internet and space is just cool. It's an exciting topic for lots of people.

3. Fleet Space and Lacuna Space are using LoRaWAN via a satellite for back haul in remote places.

Derek: "One of the most well-known, but definitely not the only, use case at Lacuna is tracking elephants in Africa. Increasing the ability to track and monitor them helps game wardens and governments understand the health, behavior, and locations of the elephants. It's really exciting stuff. Then over at Fleet Space, they created a little mini gateway that has a LoRaWAN and a satellite transceiver in it, so that they have a solution for these remote places in one small little box that can be portable as well.

"There's been a lot of interest in satellites and IoT, but the use case and the ROI hasn't always been there. These types of solutions have really changed that. And the innovations that these companies have created are now enabling use cases in these remote areas that just weren't really viable before. So, this is the begin-



4. LoRa Alliance Certification Flowchart.

ning of a trend that's really going to increase in the coming years."

One of the things about LoRa is that it's especially suited for satellite use, as it's the only internet of things infrastructure band that has the range. The LoRaWAN range of around, what, 500 miles is well suited for low orbit.

Derek: "It's those use cases. Again, think of agriculture and where some large farms are, think of energy, some utilities, but more oil and gas. Think of-"

Tracking containers worldwide.

Derek: "Exactly. Going over the ocean and animals, elephants in Africa. Places where there just aren't other communication technologies that can reach those locations. And even if they could, the amount of money to build a tower or put something in place or put infrastructure just is prohibited. So the satellite capability for the backhaul to reach the internet is flexible. It has the range as you said, and now it's at a cost point that actually merits investment in those places to solve those use cases that just weren't really solvable before. It's really exciting."

SECURITY IS KEY

Derek: "Security is a big focus for IoT and the LoRa Alliance. I've been involved in it as director of product management previously, trying to ensure that the solutions we're deploying out there are secure. Security is a big topic. It's not just the specification itself. What's really important is the protocol and specifications, so LoRaWAN itself is very secure. But that's not enough, because in the IoT stack, you've got many attack services and attack vectors that could be leveraged to compromise a solution.

"So implementation and management is extremely important. So, it's not just using technology, it's implementing it. Doing a proper and correct implementation, and it's amazing how often this is done incorrectly. The third piece for us is certification, which I talked about. It's people can make mistakes in developing devices utilizing any technology. The reason why secure certification for us is so important is because it absolutely tests all the security features of the LoRaWAN protocol of that device so that when they get the LoRaWAN certification mark, they know, their customers know, we know that it is a very secure part of the solution.

"That's security at its root, it's all about trust. The mark gives you the trust in that device, regardless of where you source that device from. We're about to publish a best practices, best

> "Security is a big focus for IoT and the LoRa Alliance. I've been involved in it as director of product management previously, trying to ensure that the solutions we're deploying out there are secure. Security is a big topic."

recommendations document. Then there's a lot of work that's continually done in the protocol itself. In fact, Johan Stokking, the CTO and co-founder of The Things Industries, is actually the chair of the security work group within the LoRa Alliance."

GETTING CERTIFIED

Derek: "The LoRa Alliance has created a certification program, but that is not the same as getting the regulatory certification marks. We have rules for becoming LoRaWAN certified, but in order to become LoRaWAN certified one needs to go through an authorized test house. There are some differences, because there are regional parameters. So North America, U.S. or Europe, Asia Pacific, and even within Asia Pacific there are some different rules depending on countries. Time on air for example, amount of data one can send at any one time.

"First a company would send their device off to the test house. If the test house then says that it has qualified for LoRaWAN certification, then that's sent to the LoRa Alliance and Derek's team. Then they go and they do a list of activities to finalize and give the LoRaWAN certified mark for the device and also put it up on the showcase *(Fig. 4)*.

"What's new is in the first column, where it says LoRa Alliance member, yes or no. If it was a no previously, it would've stopped. Non-members could not obtain LoRaWAN certification from the Alliance. We're the only ones that can give that LoRaWAN certified mark. However, now that we've created a certification affiliate program, now there is a pathway for those non-members companies.

"It's really important and the LoRa Alliance only promotes certified devices. Now it's clear that there are lots of non-certified devices that are out there in the world. I do not want to say that those do not perform well, but there's going to be a mix of performance from those who have developed properly to those who may have missed some things. So that's why we always promote certified devices because we know it's been empirically proven that those devices perform according to the specification."

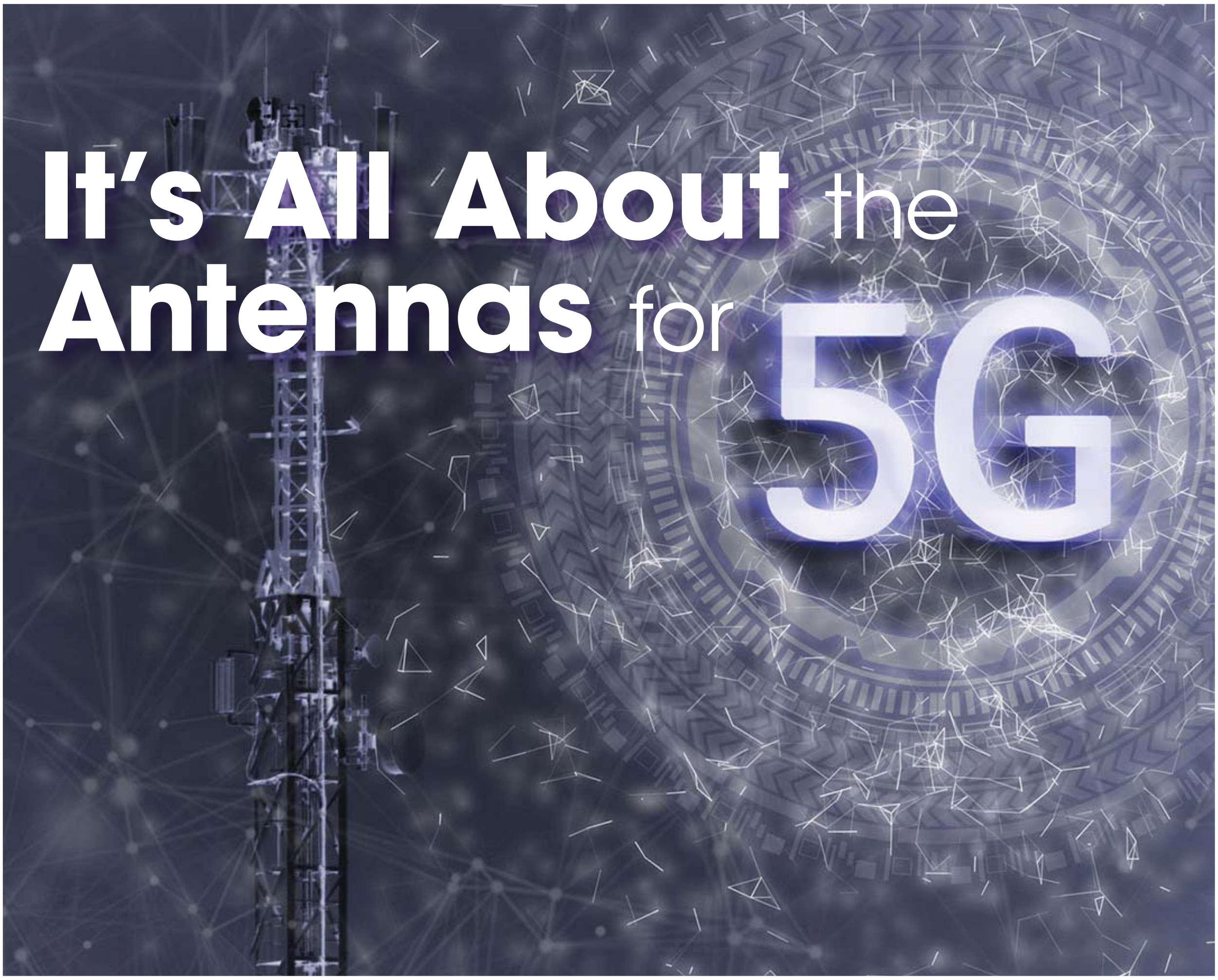
LOOKING FORWARD

Any last thoughts?

Derek: "Certification is very important. Getting as many devices out there in the world that are certified is very important for the LoRa Alliance. It's actually much more attractive for someone to become a member of the Alliance and be able to get the LCTT as part of that membership and have cheaper per device costs for certification. But still if someone just cannot or does not want to become a member, but definitely wants certification, well now they have a path." mw

LOU FRENZEL | Contributing Editor

It's All About the Antennas for 5G



For 5G technology to function as expected in apps from factory automation to self-driving vehicles, multiple antennas must be properly implemented.

When studying 5G NR operation, it's not immediately obvious that 5G meets all of the objectives of the 3GPP standard by using advanced antenna technology. Antennas are often overlooked and treated with indifference. After all, antennas are just that nuisance metal thing that you have to put on a radio to make it work. In the case of 5G, antennas play a major role in achieving the expected features and performance.

The primary objectives of 5G NR are:

- *eMBB:* Enhanced mobile broadband (eMBB) means more subscriber capacity and higher data rates. Increase subscriber capacity by at least a factor of 1,000 over LTE and boost downlink (DL) data rate to 10 Gb/s with a minimum of 100 Mb/s for every subscriber.
- *mMTC:* Massive machine-type communications (mMTC) effectively means the Internet of Things (IoT). The 5G standard meets the needs of low power consumption, low cost, and low data rate generally associated with IoT to wirelessly connect millions of different things to the internet.
- *uRLLC:* Ultra-reliable low-latency communications (uRLLC). Latency is the time delay between an initiating action and the time the action occurs. In many wireless systems, this delay is harmful or otherwise a knock-out factor.

Factory automation with robots, advanced driver-assistance systems (ADAS) that improve safety in new vehicles, and, ultimately, self-driving cars or trucks all rely on low latency.

The new 5G standard claims a latency of 1 ms or less, which should satisfy these needs.

New 5G systems are proving that these objectives can be met, especially eMBB, by using multiple antenna methods:

MIMO

The first antenna technology that leads to the highly desirable features of 5G is multiple-input, multiple-output (MIMO). MIMO uses multiple antennas plus their transceivers. The serial data to be transmitted is divided into multiple data streams, each of which modulates an individual carrier. All such signals are then transmitted simultaneously over the same bandwidth.

Because the antennas for each channel are adequately spaced, each signal will travel a slightly different path. This ensures that fading and other problems are greatly minimized, thereby improving link reliability and leading to fewer dropped calls and texts.

MIMO systems define the number of antennas and paths. For example, there may be four transmitting antennas and four receive antennas expressed as 4×4 or 4T4R. A variety of MIMO configurations can be built; 5G can define up to 8T8R.

In addition to improving link reliability, the multiple streams can boost data rate by a factor of N, where N is the number of transmit antennas. Data rates to several gigabits per second are possible. Add to that the wider channels of 40, 80, and 160 MHz plus carrier aggregation and modulation up to 64QAM and the data rate can soar.

BEAMFORMING

The other antenna technology that makes 5G work is agile beamforming. This is the process of using special antennas to produce very narrow beams that can be rotated to point in a desired direction. This technology is more likely to be used in the millimeter-wave (mmWave) bands.

Phased arrays have been used for years in the military for radar. Some are as big as a building, with others mounted on the front of a ship or in the nose of a plane. They were and are expensive.

The highly focused beams indicate that the signal has been concentrated or focused, which means the effective radiated power has been boosted. Stronger narrow beams will travel farther and sometimes penetrate buildings and other obstacles more effectively. And the ability to position beams over a wide angle makes it possible to minimize or null out strong interfering signals.

The technology that provides this capability is phased arrays. Phased arrays are panels of many small antenna elements, each with its one TX and RX plus gain control and phase variation. By adjusting the amplitude and phase out of each antenna, the signals from each antenna are summed so that they add or subtract (interfere), allowing for the generation of multiple beam sizes that can be pointed in a desired direction.

Phased arrays have been used for years in the military for radar. Some are as big as a building, with others mounted on the front of a ship or in the nose of a plane. They were and are expensive. Now you can buy a phased array on a chip. Phased arrays boost signal power, thereby extending the transmission range and helping the signals go deeper into buildings.

Oh yes, the phased arrays can be used as MIMO antennas. This makes it possible to implement multi-user MIMO, a variant of plain-old MIMO that lets one antenna be partitioned into smaller antennas, each group dedicated to one of the many users accessing the cell site.

SMARTPHONE ANTENNAS

We don't think about antennas when we're buying or using a smartphone. Yet they're more important than you think. The typical smartphone has maybe a half-dozen antennas. At least two are for the lower and upper cellular frequencies. But with 5G, MIMO must be added. To do so would require two each for the upper and lower bands. One popular combination is 4×2 (or 4T2R).

That means many, if not most, new 5G phones will have four antennas for the cellular bands. These antennas will likely have some automatic antenna-tuning capability.

Also in the mix are one or two antennas for Wi-Fi and Bluetooth. Since both wireless technologies operate at 2.4 GHz, it's possible to share an antenna. Then there's a GPS receiver antenna. If you know a little about antennas, you probably know that each individual antenna should be spaced as far away as possible from the others to avoid interaction. That's tough to do in a small handset. Thankfully, the operating frequencies are high and the wavelength and antennas short.

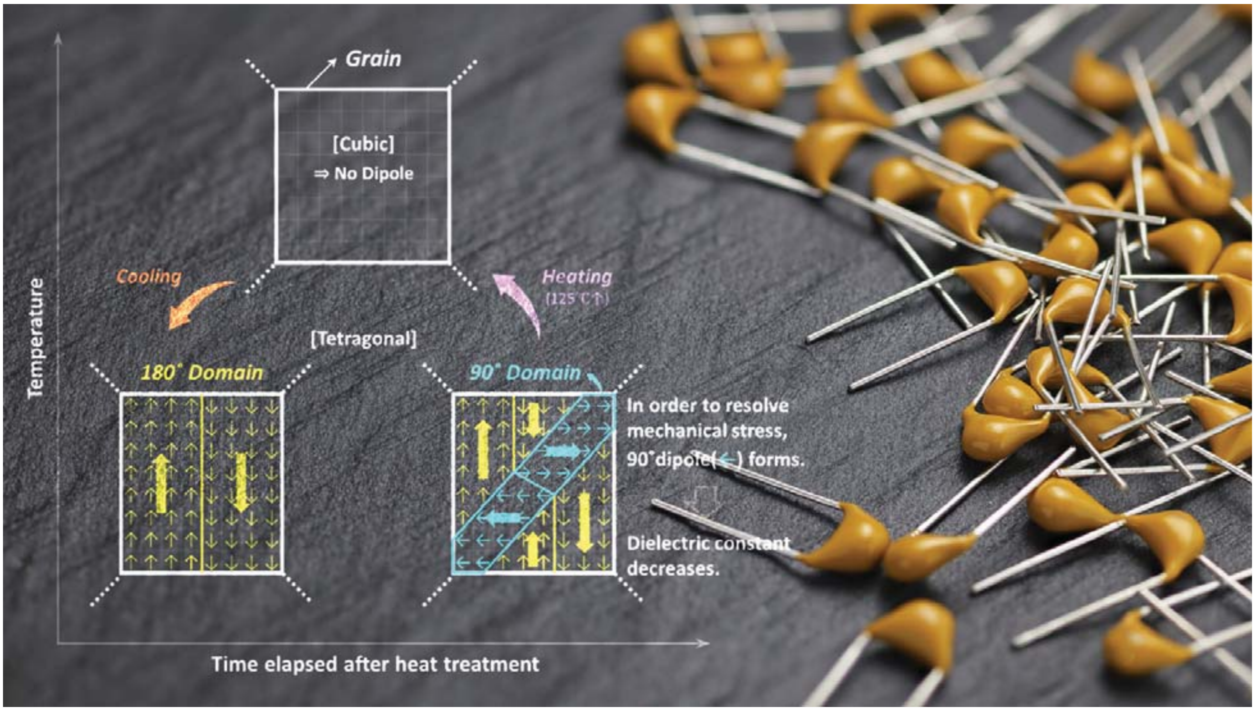
One more thing. If we're talking about a 5G mmWave phone, you will need another antenna. With 5G on the lower cellular bands, the regular smartphone antennas will work. But if you have a mmWave version of 5G, you'll have a small phased array inside the handset

I almost forgot the NFC antenna. The near-field communications radio operates on 13.56 MHz. Its antenna is usually a small coil. It too eats up lots of space inside the phone. NFC use is increasing, and it could see future new applications now that the standard has implemented two-way data exchanges.

So, it really is all about the antennas these days. Can't do without them. mw

HERB TE-JEN MA | Application Engineer Manager, Samsung Electro-Mechanics Co. Ltd. (SEMCO)

Diagnosing Class II MLCC Effective Capacitance and Aging Under DC Bias



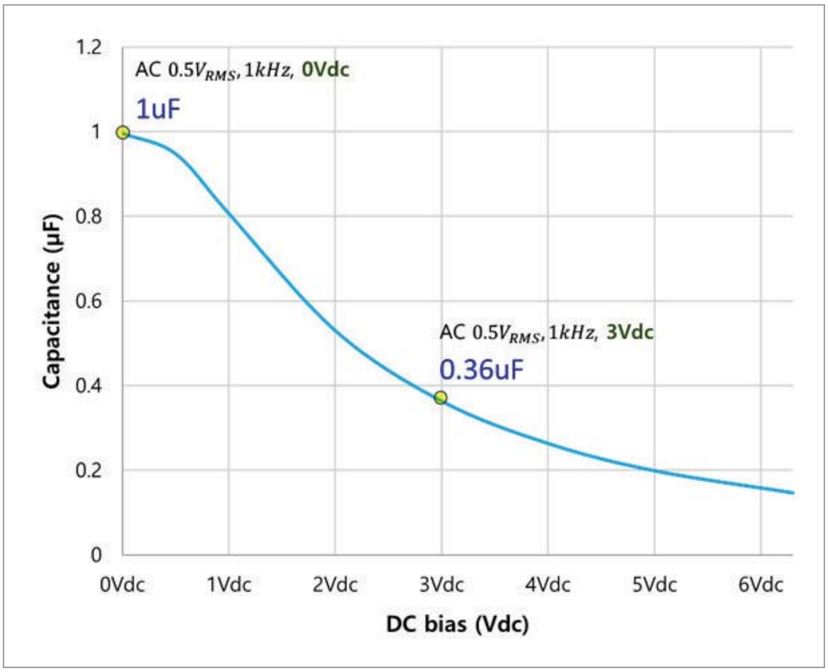
Most designers know that dc bias significantly decreases the effective capacitance of Class II MLCCs. But is it enough to estimate the effective capacitance of an MLCC just by looking at the dc bias curve? What other factors also warrant scrutiny?

For decades, multi-layer ceramic capacitors (MLCCs) have been the go-to choice for surface-mounted capacitors due to their many advantages, such as wide available capacitance range, non-polarity, low ESR, and low cost. Most designers know that the effective capacitance of Class II MLCCs can be reduced significantly when dc bias is applied across the capacitor.

However, in addition to the dc bias effect, other important factors can impact the effective capacitance of Class II MLCCs. These factors include ac bias, signal frequency, temperature, and aging. This article aims to provide a holistic view of these effects, and serve as an introduction into a less-well-known phenomenon known as "aging under dc bias."

Let's start by looking at the dc bias effect, perhaps the most efficient reducer of effective capacitance. For example, the effective capacitance of a 1-µF, 6.3-V-rated X5R MLCC can be reduced to 0.36 µF by applying 3 V dc (47% of the rated voltage). Note that the standard signal condition for dc bias measurement is 500 mV_{RMS} at 1 kHz. This shows a 64% reduction from the 1-µF nominal capacitance *(Fig. 1)*.

When dc voltage is applied, some of the barium titanate ($BaTiO_3$; the dielec-



1. In this plot, we see how effective capacitance drops as the applied dc bias voltage increases.

tric material used by Class II MLCC) dipoles are locked down. These locked-down dipoles are no longer able to move when ac voltage changes, resulting in the decrease of capacitance. The dc bias effect has been well-observed by all electrical engineers.

Now, if the ac level in the standard measurement condition is reduced from 500 mV_{RMS} to 10 mV_{RMS} while maintaining the same 1-kHz frequency and 3-V dc biasing, the effective capacitance will further drop to 0.32 µF, an additional 4% reduction. But, increasing ac signal amplitude increases the effective capacitance *(Fig. 2)*, if only to an insignificant degree. But note this isn't universally correct.

AC VOLTAGE DEPENDENCY AND DC BIAS EFFECT

The mechanism of ac voltage dependency for effective capacitance is much more complicated than that of the dc bias effect. This is due to the nonlinear permittivity of the dielectric (hysteresis effect) between the applied electric field and electric flux density. In *Figures 2 and 3*, we observe that the measured capacitance increases as the ac signal increases, but note that the capacitance begins to decrease as the amplitude of the ac signal reaches a certain level.

Another key point is that the level of dc bias also impacts the effect of ac voltage dependency on effective capacitance. When the applied dc voltage is small, the ac voltage-dependency effect becomes much more prominent and the effective capacitance may drop as much as 30% if the ac voltage amplitude is also close to null *(Fig. 3, again)*.

On the other hand, if the capacitance drop is already more than 50% due to dc bias effect *(Fig. 2, again)*, the capacitance loss due to ac signal becomes much smaller. Consequently, depending on actual signal conditions, caution must be exercised in estimating the effective capacitance by taking both dc bias and ac voltage-dependency effects into consideration.

TCC AND FREQUENCY DEPENDENCY

Two other graphs that can be found on a typical MLCC datasheet are temperature characteristics of capacitance (TCC) and frequency-dependency characteristics. Compared to dc bias and ac voltage-dependency effects, the TCC and frequency-dependency effects are much less pronounced, contributing to less than 20% of capacitance change in most cases.

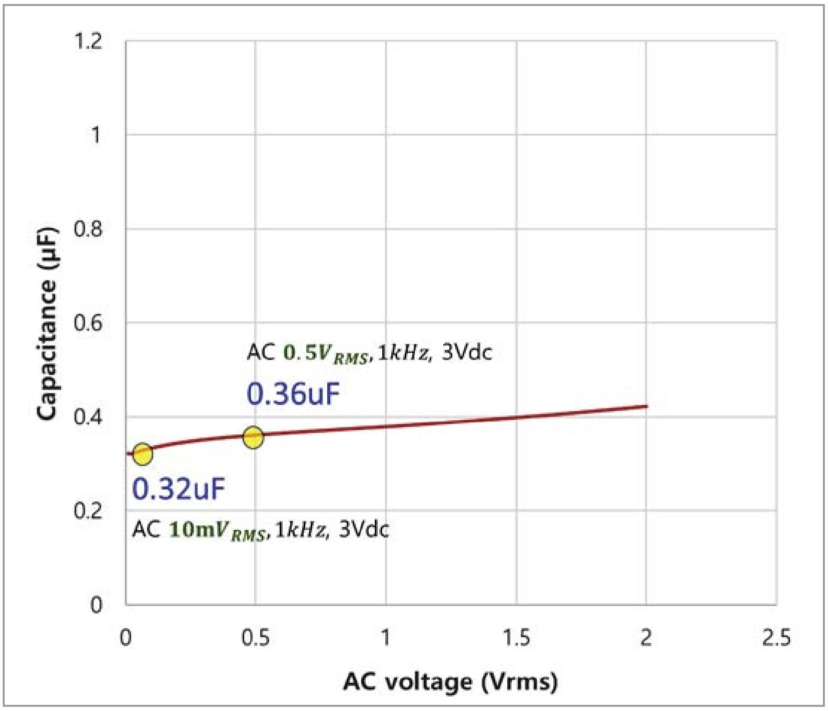
The TCC is regulated by the MLCC's dielectric type, such as X5R, X6S, X7R, and so on. Thus, it comes as no surprise that the capacitance change will be within the definition of each dielectric type; for example, a 15% change for X5R or X7R. Do note, however, that the capacitance-change range as defined by TCC is independent of the capacitance tolerance. Therefore, for a 22-µF, 20%, X7R MLCC, the initial capacitance could be as low as 15 µF in the worst-case scenario [22 µF × 80% (low end of the tolerance) × 85% (assuming it retains 85% of capacitance at 125°C) = 14.96 µF], and this is even before any voltage is applied.

Figure 4 shows how the capacitance value decreases as the frequency of ac signal increases for the same 10-V, 1-µF MLCC. The changes in capacitance become even smaller when dc bias is applied.

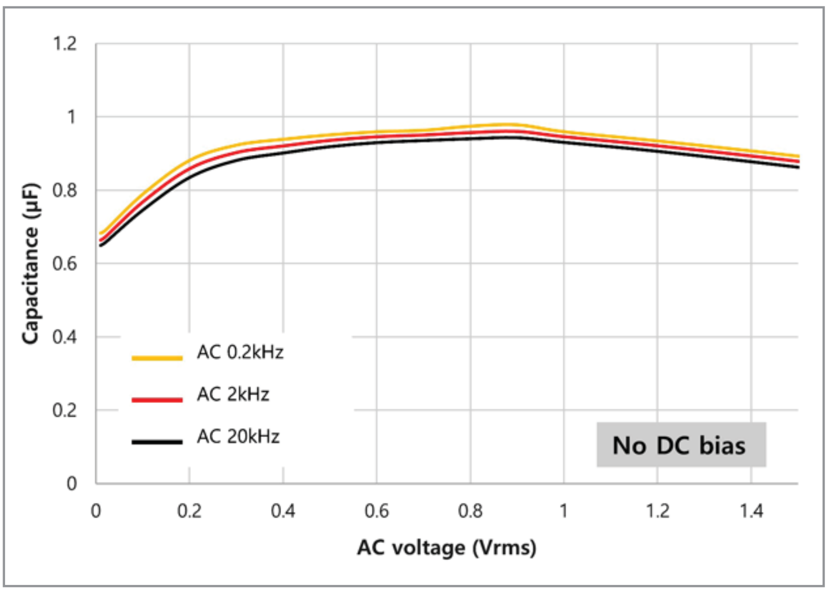
The MLCC aging effect states that the capacitance of an MLCC decreases logarithmically with time, according to the following equation:

$$C(t) = C(t_0)^*(1\text{-}k^*\log_{10}(t)),$$

where $C(t_0)$ = initial capacitance value; $C(t)$ = capacitance value, t hours after the start of aging; k = aging constant, which varies with MLCC type; and t = aging time.



2. Shown are effective capacitances at different ac voltage levels with application of a 3-V dc bias voltage.



3. The ac voltage level influences effective capacitance without dc bias applied, as shown in this plot.

The aging phenomenon is due to the internal structural characteristics of $BaTiO_3$, where the capacitance decreases as the dipoles rearrange their orientation slowly to stabilize internal mechanical stress *(Fig. 5)*. Typically, aging behavior is relatively less of a concern for two reasons. First, aging is reversible. The decreased capacitance can be recovered by heating the MLCC above 125°C, or the Curie point, at which the dipoles are realigned and the capacitance restores. Such heat treatment is called "de-aging" and is observed before nominal capacitance measurement.


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Figure 4 shows how the capacitance value decreases as the frequency of ac signal increases for the same 10-V, 1-μF MLCC. The changes in capacitance become even smaller when dc bias is applied.

Second, given the logarithmic nature of capacitance drop, the loss in capacitance is most significant within the first 1000 hours of de-aging. The effective capacitance of MLCCs essentially "stabilizes" after 1000 hours as the capacitance drop becomes trivial. Nonetheless, aging is still an important topic for designers to consider from a product reliability point of view, as almost all end products in nature have to be operational beyond the 1000-hour mark.

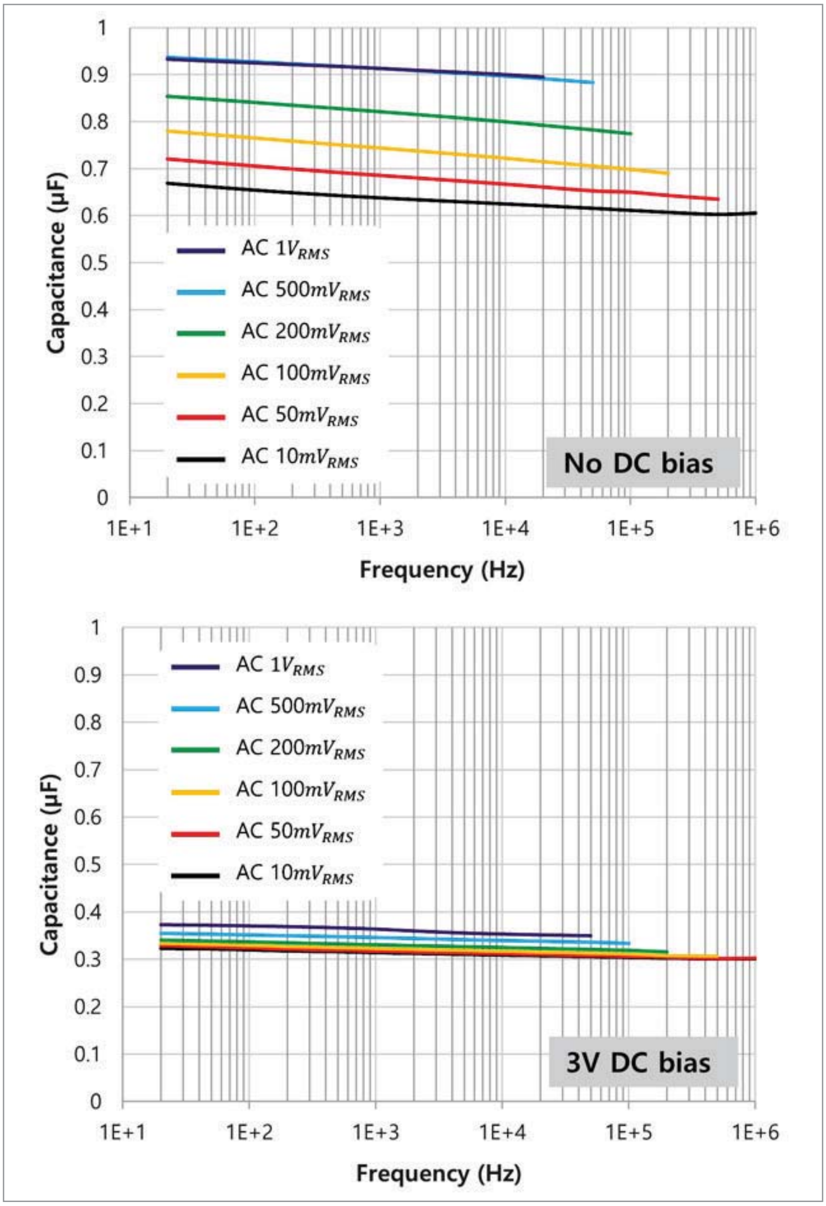
AGING AND DC BIAS

Another topic related to aging, albeit much less understood, is the capacitor's aging behavior under dc bias. This topic is much more important than it seems, as MLCCs are very often used as bypass capacitors in power rails to maintain the dc voltage of these rails. It means these capacitors are under constant dc electric fields. Intuitively, one may think that the effects of aging and dc bias are additive—the aging curve should simply shift down when dc bias is applied. This seems to be plausible as dc bias doesn't vary with time, but it's simply not the case in reality.

In the real world, the capacitor aging behavior under dc bias is shown in *Figure 6*. Initially, the effective capacitance curve drops almost immediately after a dc electric field is applied. This is the dc bias effect at work due to the dipole lockdown. After the dc bias effect lessens the effective capacitance (this happens in the order of seconds), the aging effect starts to kick in and continues to work for up to 10^5 seconds and beyond.

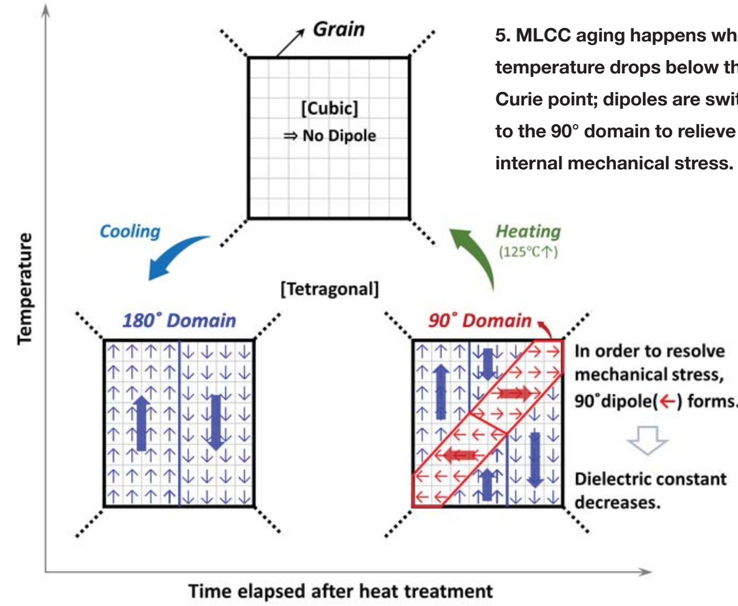
However, it should be noted that after the aging effect kicks in, the applied dc bias actually drops the effective capacitance even further down than the linear sum of capacitance drop from dc bias and from the aging effect combined. This is because during dipole switching *(Fig. 5, again)*, the dc bias actually helps the 90° dipole domain align to the $BaTiO_3$ lattice axis that has the lowest permittivity, hence the further reduction in capacitance.

Important though it may be, the aging behavior of MLCCs under dc bias has regrettably not been a focus in effective capacitance simulation. Consequently, it's not a spec that can typically be found in an MLCC datasheet. In addition, this



4. Different frequency levels also affect effective capacitance as functions of: without dc bias (top); with 3-V dc bias applied (bottom).

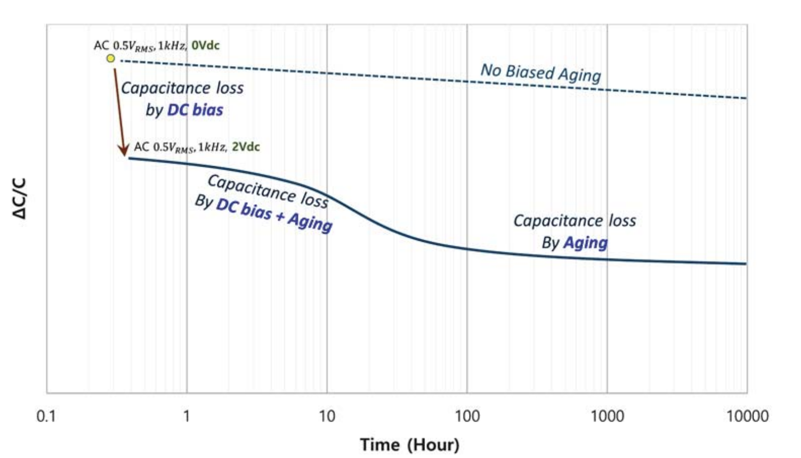
The aging phenomenon is due to the internal structural characteristics of $BaTiO_3$, where the capacitance decreases as the dipoles rearrange their orientation slowly to stabilize internal mechanical stress *(Fig. 5)*.



5. MLCC aging happens when temperature drops below the Curie point; dipoles are switching to the 90° domain to relieve internal mechanical stress.

capacitance-drop behavior depends heavily on the material type and the design structure of a given MLCC. So, for designs in which performance is sensitive to effective capacitance, experimental measurement of the actual capacitance decrease becomes the only way to accurately understand the aging-under-dc-bias behavior for a specific MLCC.

MLCCs aren't just for smaller, faster, cutting-edge devices, but rather are a building-block component found in a myriad of applications. A complete understanding of MLCC effective capacitance will not only help a designer build a system that's more stable and robust, but can also help prevent any potential reliability issues down the road, especially after end products are in the field. mw



6. The effective capacitance of MLCC aging under dc bias drops below the linear sum of capacitance drop from dc bias and when it's combined with the aging effect.

Highly Accurate Programmable Attenuator Minimizes Losses

BROADWAVE TECHNOLOGIES has developed an electromechanical 75-Ω programmable attenuator that offers an external TTL control board and BNC female connectors. Model 674-043-063 features a dynamic range of 63 dB in 1-dB steps over a frequency range of dc to 1000 MHz. According to BroadWave, the attenuator has an accuracy of ±0.5 dB or 2% of the programmed value, a 1.50:1 maximum VSWR, and insertion loss of 3.0 dB. It offers a switching speed of 10 ms; TTL control is applied via a 10-pin header and secured with a latch.

BROADWAVE TECHNOLOGIES, https://www.broadwavetechnologies.com

Midspans Support Power-Over-Ethernet in 60- to 90-W Range

MICROCHIP TECHNOLOGY has released new IEEE 802.3bt-compliant PoE midspans that enable PoE solutions in multiple power ranges (60 to 90 W), and in different port counts of 1, 6, 12, or for a range of industrial applications. The PoE midspans are compatible with the IEEE 802.3af and IEEE 802.3at standards, making integration easy with existing platforms. The new IEEE 802.3bt-compliant PoE midspans also offer single- and multi-port options, which enable new IEEE 802.3bt-compliant switches to power pre-standard PDs.

MICROCHIP TECHNOLOGY, https://www.microchip.com

Wireless Dev Kit Integrates Bluetooth, Zigbee, Thread, and More

TEXAS INSTRUMENTS' LPSTK-CC1352R SimpleLink Multi-Band CC1352R wireless MCU Launchpad SensorTag kit allows developers to prototype IoT devices with integrated wireless connectivity. The CC1352R MCU features an Arm Cortex-M4F with a dual-band radio, 2.4 GHz and sub-1 GHz, and supports 2.4-GHz radio, Bluetooth Low Energy, Zigbee, OpenThread, and 802.15.4. The kit also includes environmental and motion sensors, including ambient light (OPT3001), temperature/humidity (HDC2080), Hall effect (DRV5032), and accelerometers. It operates from AAA batteries with an option for lower power applications using a CR2032 coin cell. The kit is compatible with TI's BoosterPack Ecosystem, which is supported by the SimpleLink Starter mobile app for iOS and Android.

TEXAS INSTRUMENTS, https://www.ti.com/store/ti/en/p/product/?p=LPSTK-CC1352R

SOSA-Aligned Dual Upconverter Operates From 6 to 18 GHz

MERCURY SYSTEMS recently unveiled its industry-first SOSA-aligned, ultra-wideband, dual microwave upconverter for demanding electronic-warfare environments. The RFM3103s offers dynamic range and performance operation of 6 to 18 MHz with low phase noise and an internal local oscillator (LO). The upconverter has also been optimized for future upgradability and is packaged in a low-swap 3U module that's ideal for electronic attack, ELINT, and beamforming systems. In a standard configuration, the RFM3103s features a pair of transmitting modules installed on two OpenRFM module sites and provides adjustable parameters for instantaneous bandwidth, frequency range, and output power.

MERCURY SYSTEMS, https://www.mrcy.com/mixed-signal-processing/openvpx-microwave-transceivers/RFM3103s/

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