More Power Packed into Tinier Passive Components p27

Using RFID Tags to Reliably Track Firearms p40

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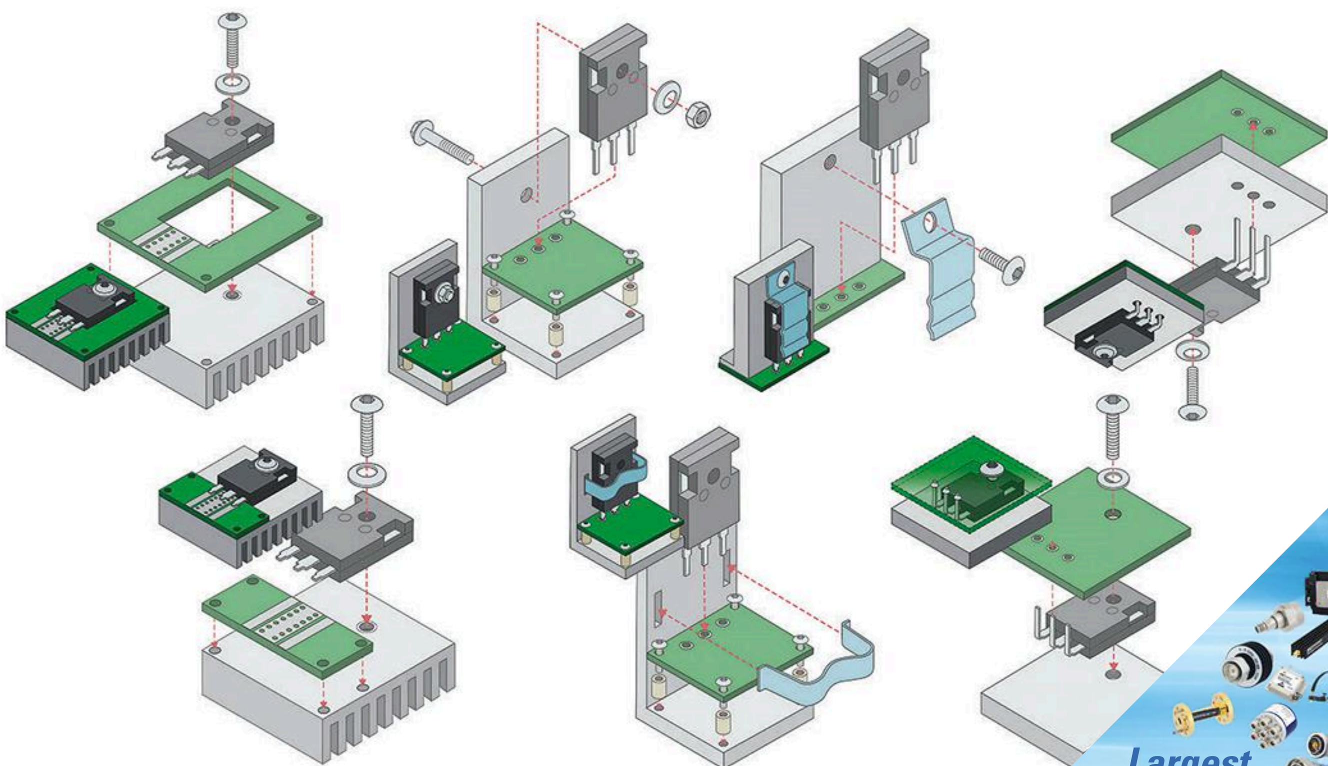
PLASTIC POWER

Real RF Power Comes to Plastic Packages

p59



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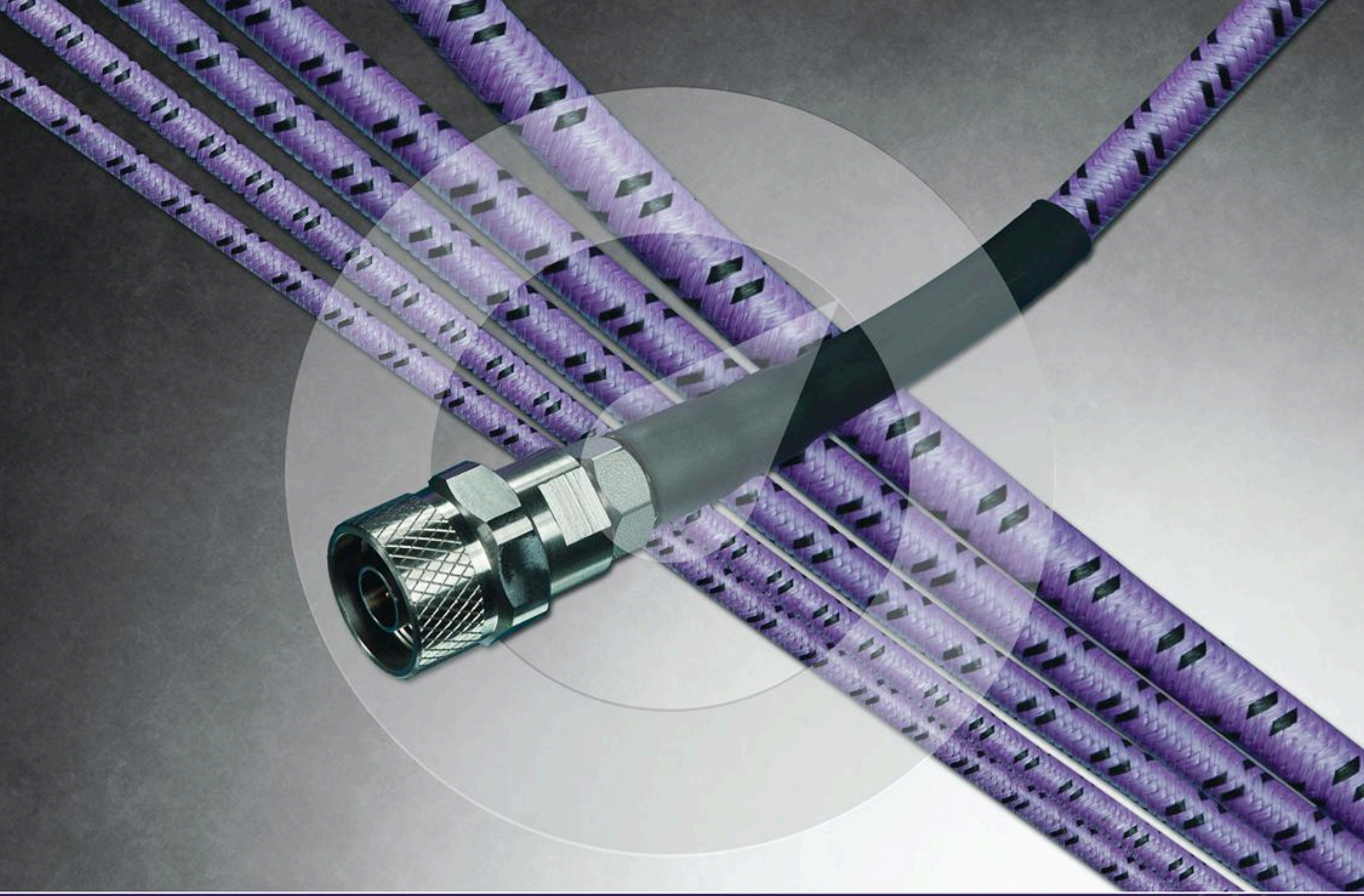

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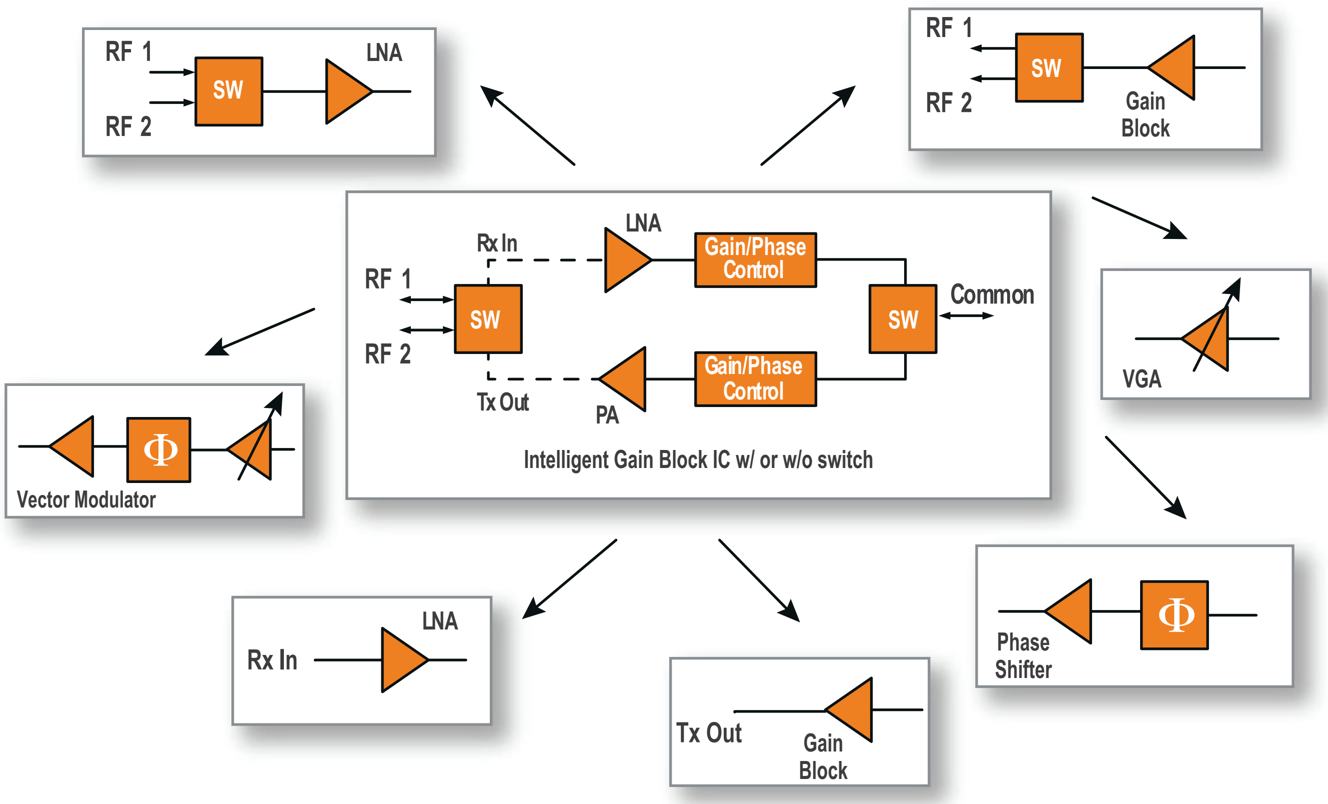

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10.5 - 16.0 GHz

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Rx: 3.0 dB NF/30 dB Gain

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26.0 - 30.0 GHz

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Rx: 5.0 dB NF/24 dB Gain

AWMF-0141

10.5 - 16.0 GHz

Tx or Rx Single Channel

Tx: 13.5 dBm OP1dB/24 dB Gain

Rx: 1.5 dB NF/30 dB Gain

AWMF-0143

26.0 - 30.0 GHz

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IN THIS ISSUE

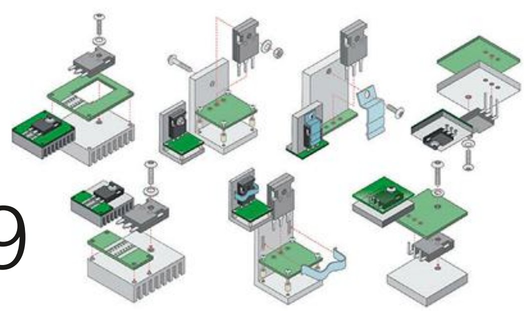
FEATURES

27

40

50

59



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NEWS & COLUMNS

62

Ultra high bandwidth Payload & RF Multipath Link Emulator

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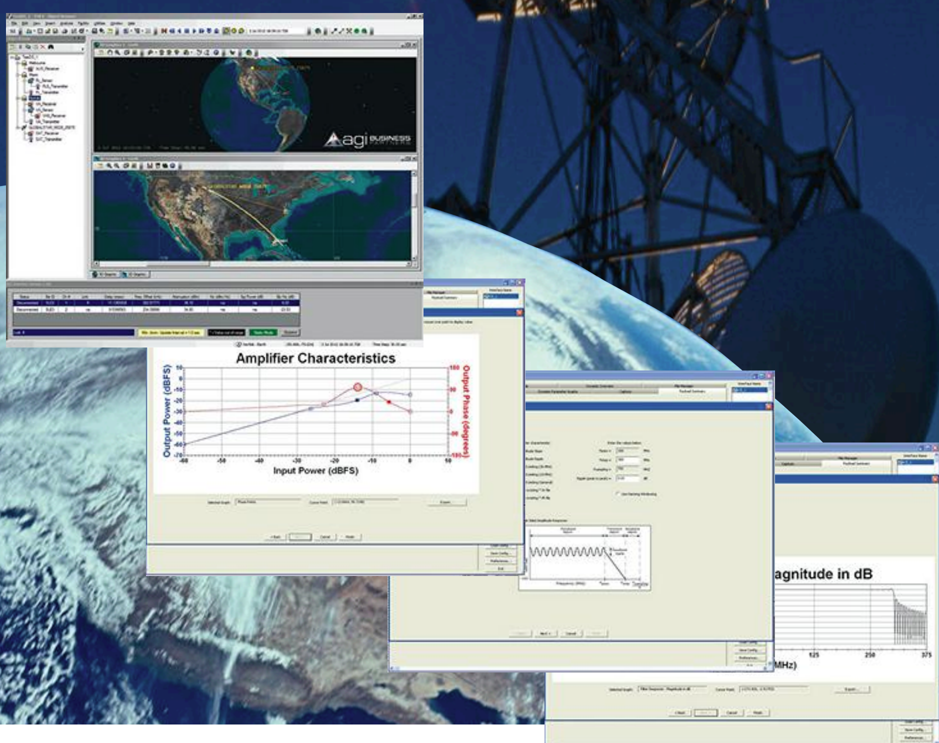

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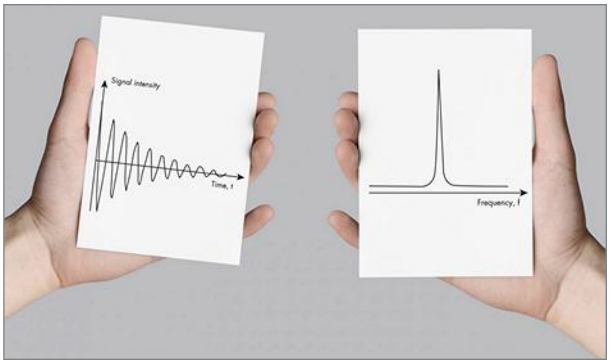


Pulsed vs. CW Signals: Both Loom on a Designer's Radar

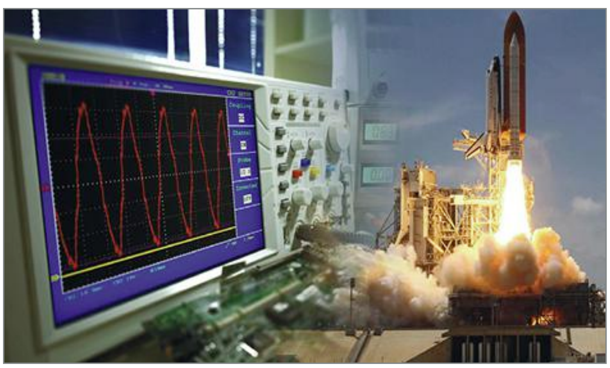
An RF/microwave system's power consumption and output power can vary significantly—it ultimately hinges on whether it's designed for pulsed or CW signals. Jack Browne dives into the differentiating details between the two types.

http://www.mwrf.com/systems/pulsed-vs-cw-signals-both-loom-designer-s-radar

High-Power Devices Have Become a High-Stakes Market

Suppliers of these devices are all in: They're not only targeting applications such as wireless communications and radar systems, but also the emerging RF energy arena.

http://www.mwrf.com/components/high-power-devices-have-become-high-stakes-market



Develop Repeatable RF Measurement Methods

These practices laid out by ISRO Satellite Centre's Kamaljeet Singh and A.V. Nirmal can lead to consistent results with test equipment, including those routines that help ensure the safety of equipment and for those at the controls.

http://www.mwrf.com/test-measurement/develop-repeatable-rf-measurement-methods

Moving Beyond TETRA and P25

Countries across the globe are turning to LTE to improve mission-critical communications. Lime Microsystems' Paul Dillien discusses how low-power programmable transceivers and open-source small cells can help ease the transition.

http://www.mwrf.com/systems/moving-beyond-tetra-and-p25

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Editorial
CHRIS DeMARTINO | Technical Editor
chris.demartino@informa.com

IMS 2018 Celebrates New Tech While Remembering the Old

The 2018 IEEE International Microwave Symposium (IMS) showcased the industry's latest innovations, and offered vignettes of its past achievements.

One takeaway from this year's IEEE International Microwave Symposium (IMS), held June 10-15 at the Pennsylvania Convention Center in Philadelphia, was how much the RF/microwave industry has changed over the years. Those who have been in this industry much longer than myself (like my colleague Jack Browne) can bear witness to that. Now that wireless technology is essentially a fundamental part of our lives, the impact that this industry has on society cannot be overlooked. And with ever-hyped 5G communications on the horizon, the industry pushes onward with new innovations.

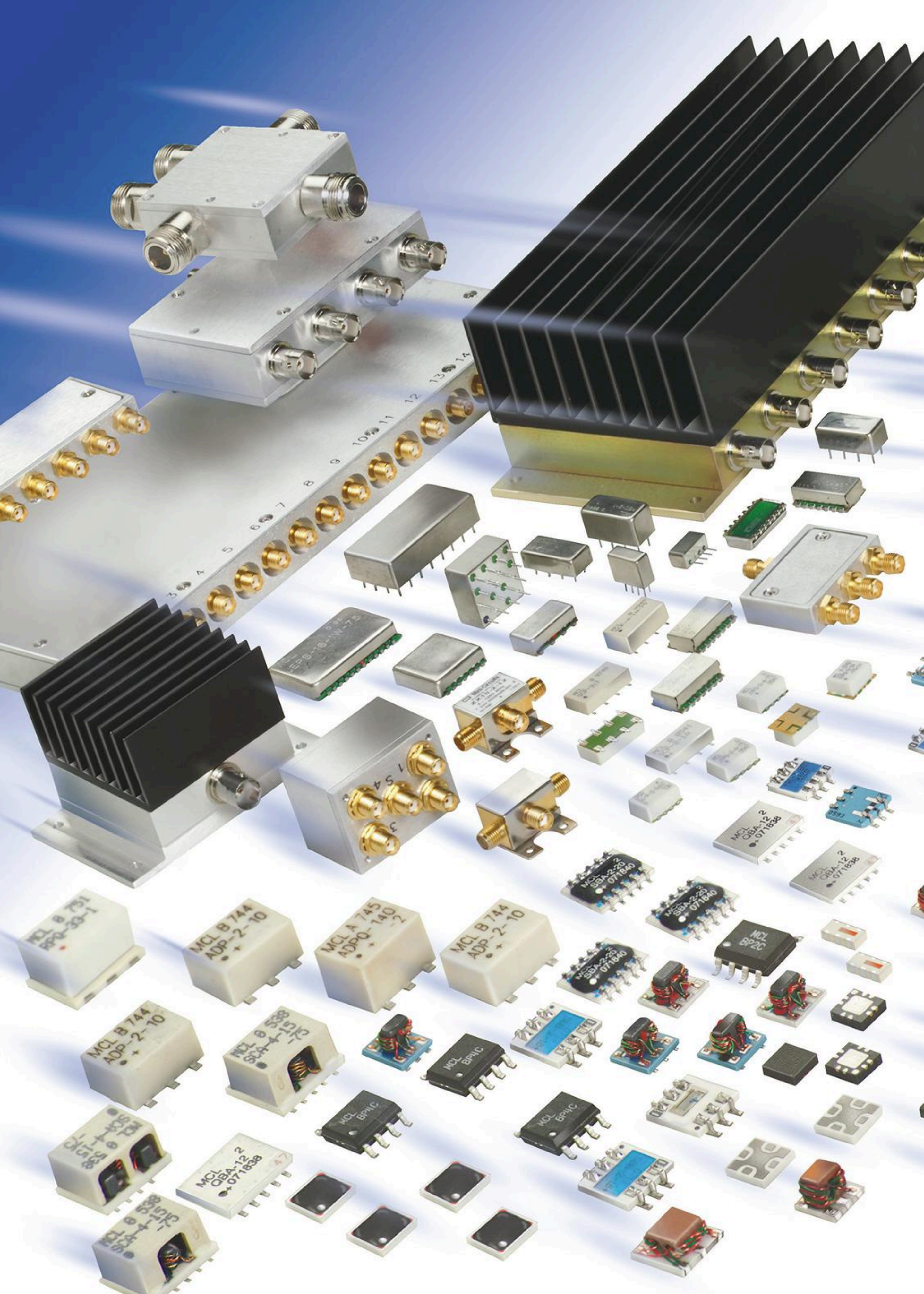
At IMS, 5G was at the center of much of the action. 5G technology was associated with anything and everything, including test-and-measurement equipment, design software, components, and interconnect products. 5G does seem to be more of a reality now in comparison to last year's IMS, as sub-6-GHz 5G deployments appear to be imminent.

Of course, sub-6-GHz frequencies only represent part of the 5G landscape. As many already know, millimeter-wave (mmWave) frequencies are also expected to play a key role. However, most agree that mmWave 5G deployments are still probably a couple years away.

High-power gallium-nitride (GaN) technology was also on display at IMS *(see page 18)*. And though companies are achieving enormous amounts of power with GaN, some say that its full potential has yet to be reached. And getting back to 5G, what role will GaN have there? Will GaN devices appear in 5G handsets? We will see how that all plays out. Furthermore, while GaN does seem to get all the attention, LDMOS technology is still alive and well *(see page 18, again)*.

Speaking of high-power applications, RF energy also had a presence at IMS. One company even introduced a connector dedicated to RF energy applications *(see page 20)*. Stay tuned for more on this front.

In addition to myriad innovations on hand, IMS 2018 celebrated the history of the RF/microwave industry. For example, Rohde & Schwarz displayed a vintage network analyzer from 1950. And a mini-exhibition showcased the industry's past by displaying systems, components, and more from decades ago, such as the BC-1068 IFF receiver. In the end, IMS demonstrated that the RF/microwave industry is one that should be recognized for its past and present technology, as well as for what is expected to come. mw



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OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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News

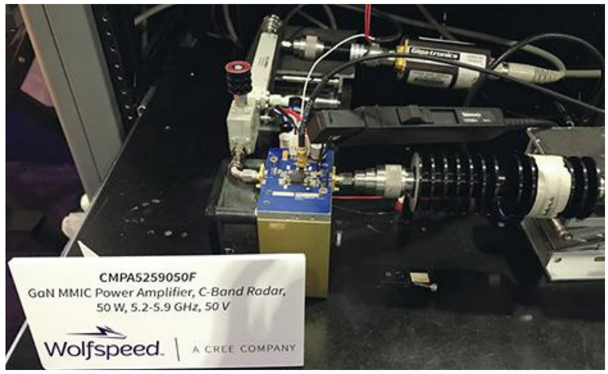
HIGH POWER LEAVES
Its Mark on IMS

One of the main themes sweeping through IMS 2018 centered around the eye-opening innovations in the high-power arena. Among the companies showcasing this capability was Wolfspeed, which displayed its GTVA101K42EV 1400-W GaN-on-silicon-carbide (GaN-on-SiC) high-electron-mobility-transistor (HEMT). This 50-V device covers a frequency range of 960 to 1,215 MHz and achieves about 17 dB of gain. Visitors to Wolfspeed's booth were able to see the GTVA101K42EV in action (*Fig. 1*).

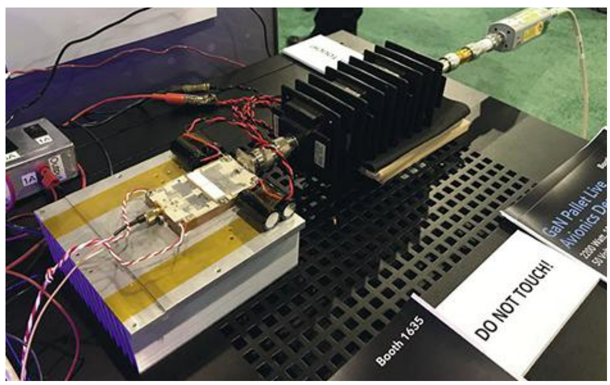
Wolfspeed also demonstrated its CMPA5259050F GaN monolithic-microwave-integrated-circuit (MMIC) power amplifier (PA) (*Fig. 2*). This 50-W PA operates from 5.2 to 5.9 GHz, and is intended for C-band radar applications.

Microsemi revealed its capabilities in the realm of high-power RF with the 1011GN-2200VP, which is a 2,200-W GaN pallet (*Fig. 3*). A live demonstration on the IMS show floor proved that the 1011GN-2200VP can indeed deliver 2,200 W of output power (*Fig. 4*).

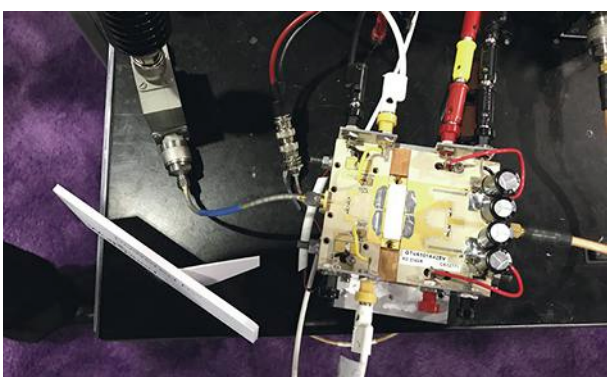
Not to be outdone, Ampleon put the spotlight on its high-power products, particularly the BLF989 RF power transistor that's designed for UHF broadcast applications. *Figure 5* (taken from the IMS show floor) shows two BLF989 power transistors in a Doherty configuration. The BLF989 covers a frequency range of 400 to 860 MHz. It can deliver 140 W of average power (700 W peak) while achieving a typical efficiency of 34%.



2. Wolfspeed gave visitors a chance to see the CMPA5259050F up close at the IMS 2018 exhibition.

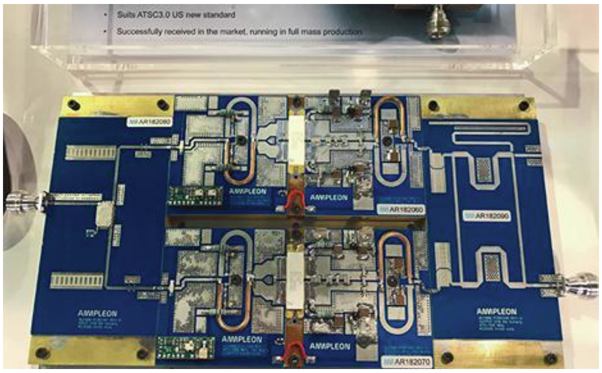


3. The 1011GN-2200VP is a 2,200-W GaN pallet developed by Microsemi.

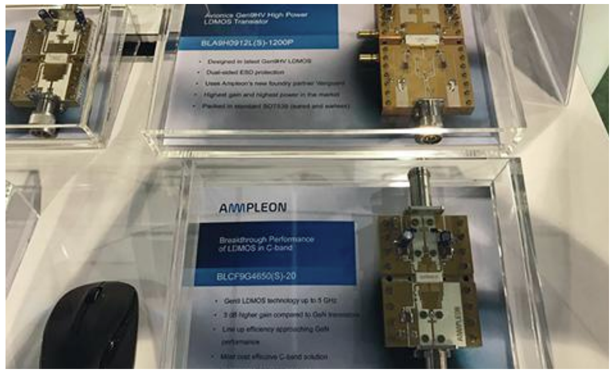


1. The GTVA101K42EV 1400-W GaN-on-SiC HEMT operates from 960 to 1,215 MHz.

4. A demonstration proved the performance of the 1011GN-2200VP, as the measured output power exceeded 2,200 W.



5. **This photo shows two BLF989 RF power transistors in a Doherty configuration.**

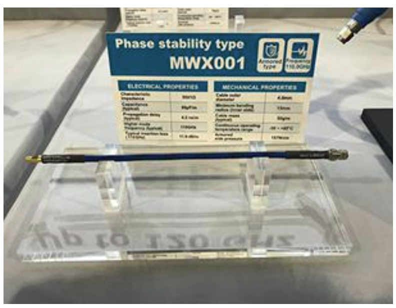


6. **The BLA9H0912L(S)-1200P and the BLCF9G4650(S)-20 devices are both based on laterally-diffused metal-oxide-semiconductor (LDMOS) technology.**

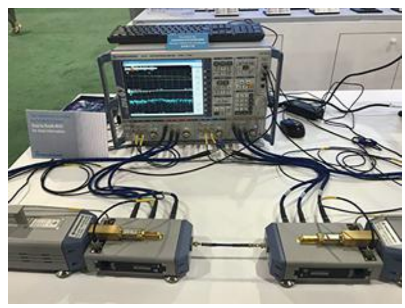
Other high-power products showcased by Ampleon include the BLA9H0912L(S)-1200P and BLCF9G4650(S)-20 devices based on laterally-diffused metal-oxide-semiconductor (LDMOS) technology (*Fig. 6*). The BLCF9G4650(S)-20 offers what the company describes as "breakthrough" performance, as it operates at frequencies as high as 5 GHz. Ampleon boasts that it offers 3 dB higher gain than GaN transistors. ■

INTERCONNECT SOLUTIONS Hook Up at IMS

WHILE INTERCONNECT PRODUCTS may not always seem glamorous, they are essential elements in creating successful RF/microwave applications. At IMS 2018, the latest and greatest high-frequency interconnect solutions were exhibited by companies that specialize in this arena. For one, those looking for robust cables at millimeter-wave (mmWave) frequencies may want to consider Junkosha *(www.junkosha.co.jp/english)*. Among the mmWave solutions on display was its MWX001 cable (*Fig. 1*).



1. The MWX001 cables offer performance to 110 GHz.



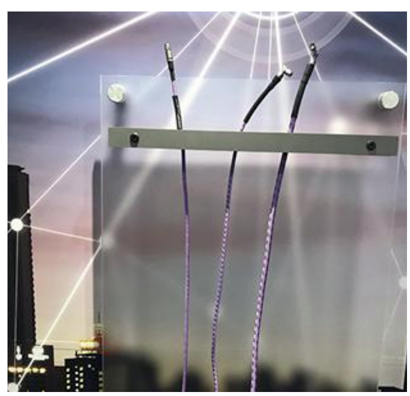
2. This demonstration revealed that the MWX001 cable had about 2 dB of insertion loss at 110 GHz.

Junkosha even demonstrated an actual measurement of the MWX001 at its booth, showing visitors that the cable's insertion loss is around 2 dB at 110 GHz (*Fig. 2*). Furthermore, the MWX001 has a typical propagation delay of 4.2 ns/m. It has an outer diameter of 4 mm.

In addition, Junkosha gave a live demonstration of its MWX051 cable, revealing how this cable maintains phase stability at 50 GHz when being repeatedly flexed. These cables are well-suited for vector-network-analyzer (VNA) measurements at higher frequencies. The MWX051 features a high tensile strength, a low dielectric constant, and high flex life thanks to Junkosha's "precision engineered expanded-PTFE wrapping technology." Junkosha's new cables illustrate how the company is focused on supporting tomorrow's 5G requirements and more.

In addition, W.L. Gore & Associates *(www.gore.com)* showcased its GORE PHASEFLEX Microwave/RF Test Assemblies, ON Cables for high-density test/interconnection applications (*Fig. 3, left*). The company boasts that these test assemblies "ensure consistent, repeatable measurements with stable electrical performance up to 50 GHz."

With their flexibility, light weight, and small diameter, the GORE PHASEFLEX Microwave/RF Test Assemblies, ON Cables allow for easier routing in cramped spaces.



3. With performance to 50 GHz, the GORE PHASEFLEX Microwave/RF Test Assemblies, ON Cables are ideal for 5G applications and much more.

In addition to reducing the stress on test ports and devices-under-test (DUTs), the cables maintain phase and amplitude stability when flexed. In terms of use cases, these cables will fit modular test instruments, RF switches, 5G applications, and more.

W.L. Gore & Associates also highlighted the GORE-FLIGHT Microwave Assemblies, 6 Series lightweight cable solutions, which have been qualified to stringent specifications for airframe assemblies (*Fig. 4*). According to the company, these cable solutions deliver low insertion loss before and after installation, ensuring reliable performance for the life of the system. Typical applications include airborne electronic surveillance/countermeasures, radar warning (electronic defense) systems, missile-approach warning systems, radar interconnects, electronic/signal intelligence, and navigation/communication systems.

4. The GORE-FLIGHT Microwave Assemblies, 6 Series lightweight cable solutions are qualified to meet stringent specifications for airframe assemblies.

Another company displaying a range of connectivity solutions at IMS was HUBER+SUHNER *(www.hubersuhner.com).* One that got the spotlight was the RFEX, a connector dedicated to RF energy applications (*Fig. 5*). With the RFEX, the coaxial structure is integrated into the housing body. This eliminates gaps caused by separate mounted connectors or feedthroughs, minimizing potential sources of RF leakage. The RFEX also features an antenna mounted to the top of the housing, making it ideal for connecting to rectangular waveguides, dielectric-filled waveguides, and cooking cavities. ■

5. Intended for RF energy applications, the RFEX integrates a coaxial structure into the housing body.

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Standard lengths in stock, custom models available. Standard lengths from 3" to 50" are in stock for same-day shipping. You can even get a Designer's Kit, so you always have a few on hand. Custom lengths and right-angle models are also available by preorder. Check out our website for details, and simplify your high-frequency connections with Hand Flex! *RoHS compliant*

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MMICS ON PARADE at IMS

SUPPLIERS OF MONOLITHIC microwave integrated circuits (MMICs) made their share of announcements at IMS 2018. For instance, Custom MMIC *(www.custommmic.com)* announced its new CMD283C3 low-noise amplifier (LNA) (*Fig. 1*). This LNA operates from 2 to 6 GHz, delivering 26 dB of gain while achieving a noise figure of 0.6 dB. The company describes this noise figure as "breakthrough," noting that such performance would typically only be achieved by discrete designs.

1. This new LNA achieves a noise figure of only 0.6 dB.

Custom MMIC also announced the CMD262 GaN power amplifier (PA), which covers a frequency range of 26 to 28 GHz. It delivers 6 W of saturated output power (P_{sat}) and achieves a power-added efficiency (PAE) of 28% at P_{sat}. Another reveal was the CMD249P5 distributed PA—it operates from dc to 20 GHz and provides +30 dBm P_{sat}.

Designers should also take note of Custom MMIC's new line of gallium-arsenide (GaAs) attenuators. These products include the CMD279 and CMD280 five-bit digital attenuators. The CMD279 covers a frequency range of 2 to 30 GHz, while the CMD280 operates from dc to 30 GHz. Both have an attenuation range of 15.5 dB along with an input third-order intercept (IIP3) point of +42 dBm. Also in the mix are the CMD281 and CMD282, which are two-bit digital attenuators that operate from dc to 40 GHz. The CMD281 provides an attenuation range of 6 dB, while the attenuation range of the CMD282 is 12 dB.

2. Shown is a new high-linearity mixer that has an RF/IF frequency range of 0.1 to 5.0 GHz.

While Guerrilla RF (*www.guerrilla-rf.com*) was not exhibiting at IMS, the MMIC supplier did introduce new products in time for the event. For one, the company announced a new line of frequency-conversion products with the unveiling of the GRF7001 high-linearity mixer with an integrated local-oscillator (LO) buffer (*Fig. 2*). The GRF7001 can be used as either an upconverter or downconverter. Its RF/IF frequency range is 0.1 to 5.0 GHz, while its LO frequency range is 0.1 to 4.0 GHz. Furthermore, the LO buffer operates from a supply voltage anywhere between 3.0 and 5.0 V. I_{dd} ranges from 10 to 30 mA.

Guerrilla RF also announced the GRF2373 and GRF2374 LNAs/driver amplifiers. The GRF2373 operates from 100 MHz to 3.8 GHz, while the GRF2374 covers a frequency range of 100 MHz to 4.2 GHz. The amplifiers are well-suited for small cell, cellular booster, and repeater applications. The GRF2373 achieves 18.5 dB of gain, while the GRF2374 provides 16.5-dB gain. Typical bias conditions of both are 3.3 V and 15 mA.

In yet another announcement, Guerrilla RF introduced its AEC-Q100 portfolio of devices to meet the demand for automotive applications. The first two products to be AEC-Q100 certified are the GRF2073 ultra-low-noise amplifier and the GRF4002 broadband LNA/linear driver amplifier. The GRF2012 amplifier is also planned to be the company's next AEC-Q100 certified product. ■

SUBMILLIMETER-WAVE TRANSCEIVER CHIP
Tunes Across 70-GHz Bandwidth

Researchers from the Institute of Microelectronics and Integrated Circuits, Universitat der Bundeswehr, Muenchen, Germany, and Infineon Technologies, Neubiberg, Germany, reported on a single-chip transceiver with on-chip antennas and continuous frequency coverage from 305 to 375 GHz that's well-suited for high-data-rate wireless communications. The integrated circuit includes a push-pull voltage-controlled oscillator (VCO), frequency mixer, intermediate-frequency (IF) amplifier, and three-stage power amplifier in addition to the integrated antennas.

The transceiver demonstrates effective isotropic radiated power (EIRP) of +18.4 dBm at 343 GHz with phase noise of −79 dBc/Hz offset 1 MHz from the carrier. Intermediate-frequency (IF) conversion gain is 28 dB with a fundamental mixer frequency-conversion architecture.

The submillimeter-wave transceiver IC is fabricated using a 130-nm silicon-germanium (SiGe) BiCMOS semiconductor technology. The VCO handles the frequency mixing. It provides fundamental-frequency and doubled-frequency outputs, which are used with the frequency mixer, and a divide-by-64 on-chip divider as part of the frequency-conversion plan.

Separate on-chip rectangular patch antennas are used for the transmit and receive functions. These are rectangular patches with multiple metal layers and a metal ground plane for optimal radiation efficiency. They are formed by combining two quarter-wavelength resonant sections to form a half-wavelength radiating patch. An array of viaholes is used between the metal layers and the ground plane with a ground ring surrounding the patch for consistent performance. Using on-chip antennas at these high frequencies is more efficient than the high losses suffered by external antennas at such high submillimeter-wave frequencies.

The patch antenna was simulated with several modeling software tools, including the three-dimensional (3D) ANSYS High Frequency Structure Simulator (HFSS) electromagnetic (EM) simulation software and the 3D planar EM simulation software from Sonnet Software, which yielded similar results. For testing, the transceiver IC was mounted to a two-sided printed-circuit board (PCB) with a brass plate attached to the PCB using conductive epoxy glue to help with the cooling.

See "Fully Integrated Single-Chip 305-375-GHz Transceiver With On-Chip Antennas in SiGe BiCMOS," *IEEE Transactions on Terahertz Science and Technology*, Vol. 8, No. 2, May 2018, p. 329.

DISTRIBUTED AMPLIFIERS Challenge Wide Bandwidths

DISTRIBUTED AMPLIFIERS MAY BE better known in their electron-tube forms as traveling-wave-tube amplifiers (TWTAs), although their goal by any name is to provide reasonable gain and output power over a wide bandwidth. Most engineers may not realize that these are amplifier designs with roots in the 1930s and 1940s, during which times they were based on vacuum-tube active devices rather than solid-state transistors.

But to some researchers, these wide-bandwidth amplifiers are quite useful at high frequencies whether in solid-state or electron-beam form. Gholamreza Nikandish, Robert Bogdan Staszewski, and Anding Zhu with the School of Electrical and Electronic Engineering of University College Dublin, Dublin, Ireland, collected summaries of the state-of-the-art distributed amplifiers in different solid-state device technologies to show what can be done in terms of performance.

As the researchers note, the first monolithic microwave integrated-circuit (MMIC) version of a distributed amplifier, based on gallium-arsenide (GaAs) metal-epitaxial-semiconductor field-effect-transistor (MESFET) technology, was demonstrated by Yalcin Ayasli of Varian Associates in 1982. The amplifier had four 1-μm-gate-length MESFET devices and achieved 9-dB gain from 1 to 13 GHz.

Although the many researchers represented by the work on distributed amplifiers worked in so many different solid-state device technologies, they were facing similar design challenges in terms of reaching for wide bandwidths, high gain, and high power-added efficiencies (PAEs).

Capacitive coupling is one way to reduce the parasitic input capacitance that limits the bandwidth of a distributed amplifier. Placing a capacitor in series with the gate of the transistors reduces the effective input capacitance, and a large resistor is placed in parallel with the capacitor to provide a path for the gate bias. This reduces the voltage gain of the distributed amplifier because of the voltage division (the resistor) at the input of the transistors.

Another way to reduce the capacitive loading effect of the transistors' input impedance in a distributed amplifier uses a common-source amplifier with RC degeneration as the gain stage in the distributed amplifier. The amplifier's input impedance is derived as a series resistance and capacitance. When the circuit elements are set properly, the input capacitance of the overall amplifier is reduced, although with degraded transconductance.

The researchers provide a collection of tables listing high-performance distributed amplifiers based on different solid-state technologies, including GaAs, InP, GaN, and SiGe BiCMOS, with bandwidths as wide as 180 GHz (with InP and SiGe semiconductor processes). They note that the trends of increasing bandwidth should continue if anything, with higher-power amplifiers as a result of the availability of GaN semiconductor processes.

See "The (R)evolution of Distributed Amplifiers," *IEEE Microwave Magazine*, June 2018, Vol. 19, No. 4, p. 66.


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Passives Cram More Power into Ever-Smaller Packages

The trend throughout the high-frequency industry is to design passive components that can handle higher power levels with effective thermal management in tighter spaces.

Passive components, such as filters or attenuators, are often called upon to make critical changes to an RF/microwave filter in terms of amplitude or waveform shape. Modern system designers, however, are relentlessly faced with shrinking a system's size, and usually without reducing the expected output power from that system. This means that passive components must get smaller while they provide increased power-handling capabilities.

In walking the exhibition floor at the recent IEEE International Microwave Symposium (IMS), trends in passive components were clear, with many suppliers extending their product lines to higher power levels and higher frequencies—many well into the millimeter-wave region—while pursuing ever-smaller packages to help system designers reach their goals for lighter weight and smaller size.

Passive components tend to be taken for granted at the systems-design level, because of their lack of active circuit elements, such as transistors, and need of a power supply. In many cases, a passive component, such as a coupler or power divider, can be added to a system whenever there's enough space for them. Of course, this assumes that any passive component squeezed into a tight space can also dissipate whatever heat it generates by handling high signal power levels.

Directional couplers are one of the more common passive components added to a system after a certain design stage, usually to perform monitoring or testing purposes. Companies with broad product lines, such as Mini-Circuits, stock a variety of couplers for handling power levels as high as 250 W at frequencies from 5 kHz to 18 GHz. These couplers are available in core-and-wire and low-temperature-cofired-ceramic (LTCC) surface-mount designs as small as 0.12 × 0.06 in.

In addition to its many 50-Ω miniature surface-mount and coaxial components, Mini-Circuits also offers 75-Ω passive components for such applications as cable-television (CATV) systems. Components like the model SXPS-4-13-75+ four-way, 0° surface-mount power splitter/combiner are designed with the higher impedance for use from 5 to 1300 MHz *(Fig. 1)*. The divider/combiner measures just 0.44 × 0.74 × 0.19 in. and comes in a shielded package with wraparound terminations to simplify soldering. Suitable also for DOCSIS systems, the component controls amplitude unbalance within 0.25 dB and phase unbalance within 1° across that wide frequency range. The typical full band insertion loss is 1.5 dB or less.

ARRA is well known for its passive components, in both coaxial and waveguide forms, built into rugged metal housings. While its components don't necessarily follow the trend in miniaturization at higher frequencies, the firm offers a wide range of passive components that have been tested to perform with high reliability, including several types of fixed and variable attenuators, couplers, power dividers/combiners, and terminations for use at RF through millimeter-wave (mmWave) frequencies.

1. Following an industry trend in "smaller and higher-power" passive components, model SXPS-4-13-75+ four-way, 0° surface-mount power splitter/combiners are designed with higher impedance for use from 5 to 1300 MHz. *(Courtesy of Mini-Circuits)*

As an example, Form 0-3190 miniature stripline directional couplers use SMA female connectors to handle 50 W average power and 3 kW peak power across a frequency range of 500 MHz to 18 GHz. They maintain low insertion loss of only 0.5 dB across the full frequency band.

MOVING HIGHER

Traditionally, passive RF/microwave components have been somewhat large, at least in package sizes large enough to support the use of coaxial connectors. As the push toward 5G wireless networks and commercial automotive radar systems encourages the use of passive components in the mmWave frequency range, many passive-component suppliers are higher-frequency components. Still, they are maintaining their coaxial connectors, albeit with smaller dimensions to accommodate the higher frequencies.

Krytar Inc., a long-time supplier of high-quality directional couplers and other passive components, has steadily climbed the frequency ladder with higher-frequency components, now well into the mmWave frequency range. The firm's directional couplers are available in coaxial housings *(Fig. 2)* for a total frequency range of 300 MHz to 67 GHz with coupling values of 6, 10, 13, 16, 20, and 30 dB.

As an example, model 110067006 is an extremely broadband coupler with

2. Many passive components, such as directional couplers, are supplied with coaxial connectors, such as this line of directional couplers with total frequency range of 300 MHz to 67 GHz with coupling values of 6, 10, 13, 16, 20, and 30 dB. *(Courtesy of Krytar)*

6-dB coupling maintained within ±2.5 dB from 10 to 67 GHz. It also holds amplitude within ±0.75 dB from 10 to 50 GHz and within ±1.5 dB from 50 to 67 GHz. It uses 1.85-mm connectors to handle as much as 20 W CW input power with minimum directivity of 10 dB, maximum insertion loss of 4.4 dB, and maximum VSWR of 1.80:1. It measures just 1.30 × 0.50 × 0.62 in. and weighs a mere 1.3 oz.

Many users employ these precision couplers in test-and-measurement systems, where small size isn't overly critical compared to a portable design application. Nonetheless, the size of the circuit boards and packaging is shrinking with the smaller wavelengths of mmWave frequencies, to the point where some packaging is barely large enough to support the screw mounting of high-frequency coaxial connectors, such as 2.4- and 2.9-mm connectors.

Such couplers find use in a wide range of commercial and military systems, including communications, electronic warfare (EW), and radar. In addition to its directional couplers, Krytar currently offers coaxial adapters and coaxial terminations operating through 67 GHz (essentially the company's test characterization limit for the components).

HANDLING POWER

In terms of minimizing rises in temperature as a result of high power levels, proper thermal design and management is essential to the essential tradeoff between possible power levels and miniaturization in passive RF/microwave components. This is in light of the fact that many manufacturers are faced with demands from system houses for more power in smaller packages. Meca Electronics has paid attention to the needs of the industry for high-power passive components while also meeting requirements for passive intermodulation distortion (PIM) at those high-power levels.

For example, Meca's model LPT10-NM-MO1 termination/load is designed for use from 0.380 to 6.000 GHz and can be used for wireless-communications base station and in-building applications in 4G wireless networks *(Fig. 3)*. With a robust metal housing and Type N male connectors, it achieves typical PIM performance of –170 dBc and low typical VSWR of 1.10:1. It's one of many terminations that the company offers from stock.

As manufacturers of passive components attempt to keep pace with growing demands for mmWave products for 5G and automotive radar applications, some makers of passive components have been there for a while. One company, Sage Millimeter, a long-time supplier of coaxial and waveguide passive components for microwave and mmWave applications, has routinely designed and manufactured such components as directional couplers, bandpass filters, and power dividers/combiners at mmWave frequencies.

3. The model LPT10-NM-MO1 termination/load is designed for use from 0.380 to 6.000 GHz and can be used for wireless communications base stations and in-building applications in 4G wireless networks. *(Courtesy of Meca Electronics)*

4. This WR-19 waveguide orthomode transducer (OMT) operates between 40 and 60 GHz. *(Courtesy of Sage Millimeter)*

As an example, the firm's model SAT-FU-18819-S1 is a WR-19 waveguide orthomode transducer (OMT) that operates between 40 and 60 GHz *(Fig. 4)*. The OMT separates a circular or elliptical polarized waveform into two linear, orthogonal waveforms or combines two linear polarized waveforms into one circular or elliptical polarized waveform.

The OMT shows high port isolation (40 dB) and high cross-polarization cancellation while providing a low insertion loss. It uses 0.188- × 0.188-in. square waveguide for the antenna port and two WR-19 waveguide flanges for the horizontal and vertical ports. The OMT achieves 40-dB isolation and 35-dB cross polarization with the square waveguide antenna port.

These products represent just a very small sampling of the passive components currently available to support the trends in higher-power, smaller-sized, higher-frequency products.

With the company's long time serving mmWave bands, it's well-poised for the coming requirements in automotive and 5G applications and offers many of the components not always considered as part of a passive component lineup, such as antennas. Its model SAK-AL173223-42-C1 is a custom-built, K-band sector rectangular lens antenna for use from 17 to 22 GHz *(Fig. 5)*. It delivers nominal half-power beam width of 31.5° vertically and 6.5° horizontally and 21.5 dBi nominal gain at a center frequency of 19.5 GHz. The sidelobe level is 15 dB or better from 17 to 22 GHz, and the typical return loss is 12 dB. The standard model is equipped with a WR-42 rectangular waveguide and a UG-595/U flange as its input port.

5. Many antennas, such as this custom built, K-band sector rectangular lens antenna for use from 17 to 22 GHz, are passive components that must be designed for appropriate power levels. *(Courtesy of Sage Millimeter)*

These products represent just a very small sampling of the passive components currently available to support the trends in higher-power, smaller-sized, higher-frequency products. Such devices are also having an impact on the demand for 3D electromagnetic (EM) simulation software for use in optimizing the structures and configurations of passive circuits and components at higher frequencies. At one time considered something of a luxury in a designer's tool chest, EM simulators are now being viewed as essential design partners for many engineers, to help them extract the optimum performance from a coaxial or waveguide section that's operating with a signal wavelength just a fraction of its size. mw

CHRIS DeMARTINO | Technical Editor

A Primer on Pulsed Measurements

Peak power meters and spectrum analyzers are two common instruments utilized to measure RF pulsed signals, which are frequently used in radar applications.

Continuous-wave (CW) signals are often used in RF/microwave applications. Measuring the power level of such signals typically involves a CW power sensor. Many diode-based CW power sensors have a wide dynamic range, allowing them to be an excellent choice for measuring unmodulated CW signals. However, some RF/microwave applications utilize pulsed signals rather than CW signals.

For instance, radar applications often use pulsed RF signals, which can be described as periodic bursts of an RF carrier. In essence, these signals are "on" for a certain amount of time. At the end of the "on" cycle, the signal is then "off" for a period of time. While a CW or average power sensor can be used to measure pulsed RF signals, they may not always be the most effective option. Oftentimes, measuring these signals can be performed more effectively by taking a different approach. It's therefore important to understand pulsed RF signals, as well as the techniques that can be used to measure them.

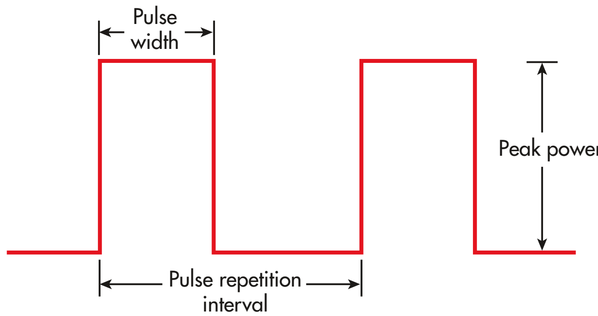
DESCRIPTION OF PULSED RF SIGNALS

Figure 1 shows an ideal pulse. Among the characteristics that describe pulses are peak power, average power, pulse repetition frequency (PRF), pulse repetition interval (PRI), pulse width, duty cycle, rise time, and fall time. PRF is the rate at which pulses are generated. PRI is inversely related to the PRF. Pulse width is simply the duration of a pulse. The peak power of a pulse can be seen clearly in *Fig. 1*. The average power of a pulse is related to its duty cycle and peak power level.

A pulse-modulated RF signal is created when a pulse modulates an RF carrier. *Figure 2* is an illustration of a modulating pulse along with an RF carrier. When the pulse modulates the RF carrier, the result is a pulse-modulated RF signal, shown in *Figure 3*.

OPTIONS FOR MEASURING PULSED RF SIGNALS

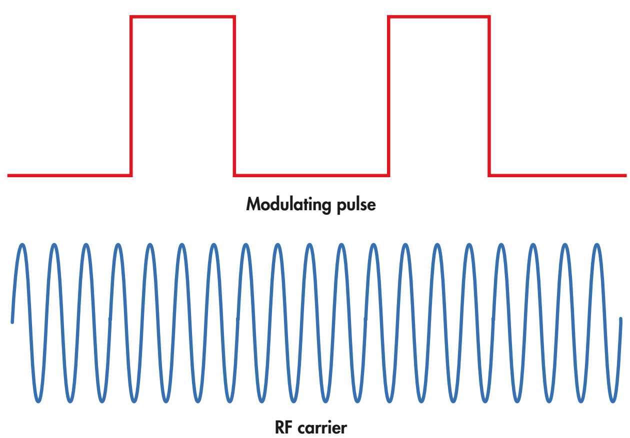
Several different test instruments can measure pulsed RF signals. Two options will be discussed here: peak power meters and spectrum analyzers. Peak power meters are essential when it comes to measuring pulsed RF signals, as they provide measurement capabilities that cannot be achieved by average power meters. They can easily analyze pulsed RF signals, allowing users to measure not only peak power, but also average and instantaneous power.



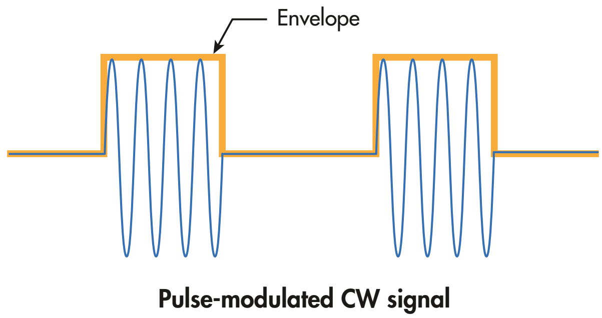
$$\text{Duty cycle} = \frac{\text{Pulse width}}{\text{Pulse repetition interval}}$$

$$\text{Average power} = \text{peak power} \times \text{duty cycle}$$

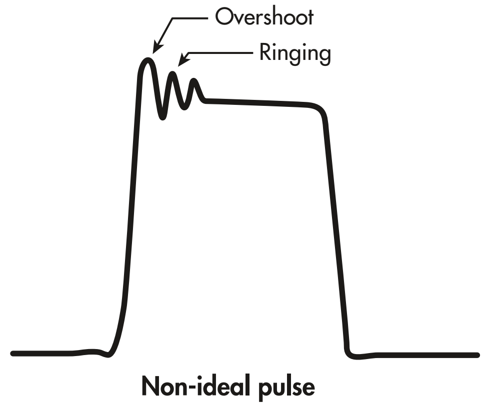
1. Shown is an ideal pulse.



2. Here, a modulating pulse sits alongside an RF carrier.



3. This figure illustrates a pulse-modulated RF signal.



4. This pulse has non-ideal characteristics.

Spectrum analyzers can be used to analyze pulsed RF signals in the frequency domain. Viewing such signals on a spectrum analyzer can reveal a number of potential problems. They do have a disadvantage in terms of cost, as spectrum analyzers are typically more expensive than peak power meters.

PEAK POWER METERS

An average power meter is commonly used to measure CW signals. Such power meters can also measure the average power of pulsed RF signals. However, average power meters cannot directly measure peak power levels.

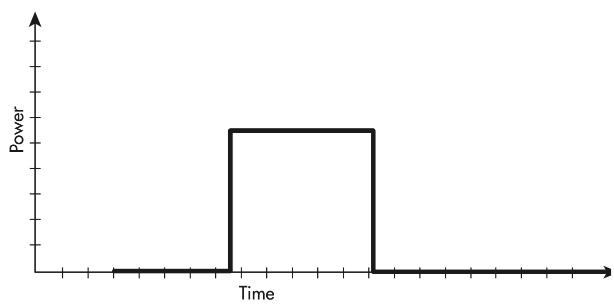
The peak power level of a pulsed RF signal can be calculated when the average power value and the duty cycle are known quantities. Thus, an average power meter is able to indirectly measure peak power. In other words, the average power is first measured. If the duty cycle is known, the peak power can be calculated mathematically as:

$$\text{Peak Power} = \frac{\text{Average Power}}{\text{Duty Cycle}}$$

However, this method of calculating peak power is only accurate in the case of an ideal pulse, such as the one shown in *Fig. 1*. *Figure 4* shows a pulse that's not purely rectangular. Additional factors, such as overshoot and ringing, result in a non-ideal shape. In this scenario, calculating the peak power by the method described will produce an inaccurate result. Thus, to calculate an accurate peak power value based on the average power value, the pulse must be purely rectangular and have a constant duty cycle. If these conditions are not met, the calculation will not be accurate.

Unlike an average power meter, a peak power meter can directly measure the peak power of a pulsed RF signal. A peak power meter would be used with a peak power sensor, which is a diode-based detector with a fast response. That response enables it to accurately measure the envelope of a pulsed signal. One drawback of peak power sensors is they generally have less dynamic range than average power sensors.

Peak power meters often have trace display capabilities, allowing one to see the envelope of a pulsed RF signal on a display (*Fig. 5*). In essence, peak power meters display a response similar to an oscilloscope. It should be noted that a peak power meter's name may actually be somewhat misleading. That's because in addition to peak power, peak power meters can measure both average power over a defined time interval and the instantaneous power at any point in time.



5. Shown is the envelope of a pulsed signal on a peak power meter display.

In addition to direct power measurements, peak power meters allow users to analyze a variety of parameters, such as pulse width, PRI, and rise/fall times. Many peak power meters also have triggering capabilities. Some provide even more advanced capabilities, such as statistical analysis.

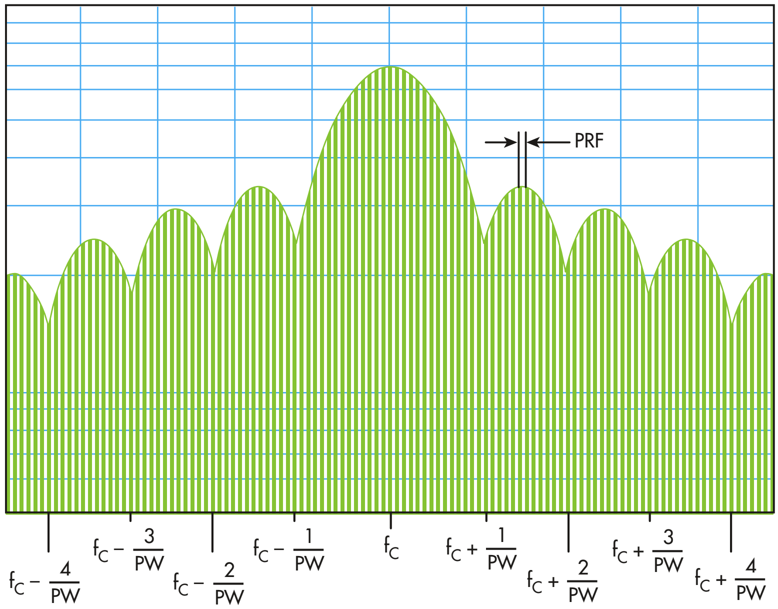
Video bandwidth is one of the most important parameters, as it must be sufficient to accurately track the envelope of a pulsed signal. Video bandwidth and rise time are inversely related. In essence, the faster the rise time of the pulse being measured, the larger the video bandwidth must be. Video bandwidth is typically specified by manufacturers.

SPECTRUM ANALYZERS

A traditional spectrum analyzer is another instrument that can be used to measure pulsed RF signals. By using a spectrum analyzer, one can analyze a pulsed RF signal in the frequency domain. Thus, a spectrum analyzer provides information that cannot be attained by a peak power meter. *Figure 6* is a generic illustration of a spectrum-analyzer display of a pulsed RF signal.

The pulsed RF signal's spectrum consists of a main lobe accompanied by side lobes. The widths of the main lobe and side lobes are inversely related to the pulse width. Essentially, as the pulse width widens, the widths of the main lobe and side lobes will decrease. The spacing between each spectral component is determined by the PRF. As the PRF increases, it also widens the spacing between spectral components.

When using a spectrum analyzer to measure pulsed RF signals, one must use the proper resolution bandwidth (RBW). The spectrum analyzer's RBW must be much less than the PRF to differentiate between each spectral component. If the spectrum analyzer's RBW is greater than the PRF, each individual spectral component cannot be displayed. However, it's still possible to preserve the shape of the spectrum. Therefore, this approach is still practical in many instances. mw



6. This is a general spectrum analyzer display when measuring a pulsed RF signal.

Design Feature

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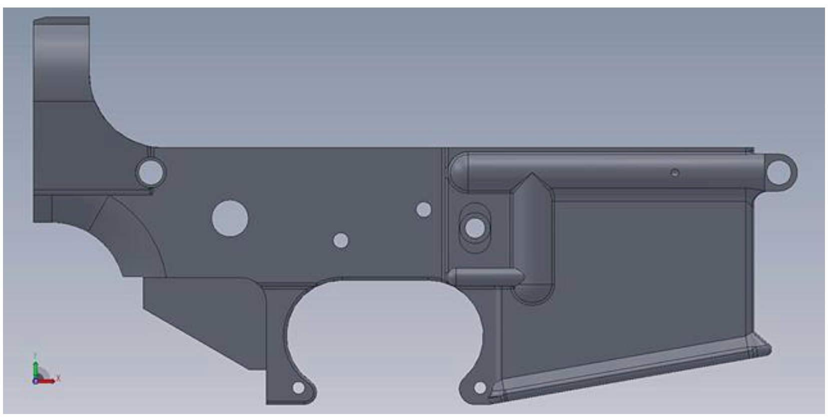
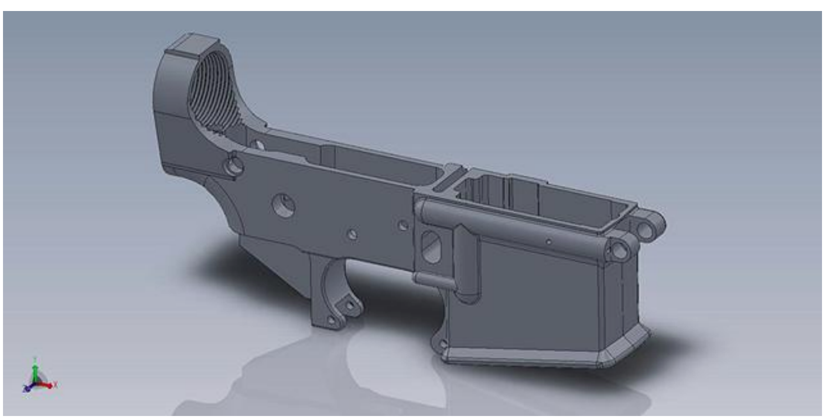
Robust RFID Tags Track Firearms

New laws are calling for the dependable tracking of firearms, and modern RFID tags can be integrated with the metal components of firearms to monitor the use of guns.

Firearms are constantly subjected to regulations and legislation in attempts to control access and limit operation only to authorized users. Many efforts have been made to track the critical components of a firearm throughout its operating lifetime, with one of the most critical firearm components referred to as the receiver. The receiver contains the trigger and the bolt. The receiver is often the only portion of a firearm that's federally regulated and required to be serialized.



1. This is one view of the lower receiver (LR) for an AR-15 firearm.



2. Here's a second view of the LR for an AR-15 firearm.

Recent development of miniature, mechanically robust radio-frequency-identification (RFID) tags provides the means of tracking firearms and their receivers in difficult environments. To demonstrate this new capability, small RFID tags will be used to track the lower receivers in AR-15 family firearms for smart gun applications.

The AR-15 lower receiver (LR) has been chosen initially for a number of reasons. It's the only component in the rifle that requires federal regulation and is serialized, making it the prime candidate for tracking. The LR being the main mechanism of the rifle also requires a significant level of routine maintenance, which makes it ideal for automated RFID tracking applications.

Additionally, this family of semiautomatic rifles is one of the broadest and most popular in the world (automatic versions include the M4 and M16). Since each RFID tag incorporates an integrated circuit (IC) with an unalterable unique identification number (UID), it provides tracking by association with the federally regulated serial number of the component. The unalterable functionality is a requirement of currently proposed new legislation (NJ

Bill A1016, which also mentions the use of RFID).

By means of RFID, the receiver is well-suited to act as the "custodian" of a firearm's history by recording within an RFIC tag's IC any pertinent information of any components that are part of the assembly. Information can be stored within any RFID IC that also contains programmable memory in addition to its UID. The storage of information occurs within the RFID tag, whose IC also has a programmable memory in addition to its UID.

Furthermore, the UID has the functionality to track/identify the original serial number of the receiver, making it possible to identify firearms when the serial numbers are removed. The RFID IC's programmable functionality can also be locked, making it unalterable if required.

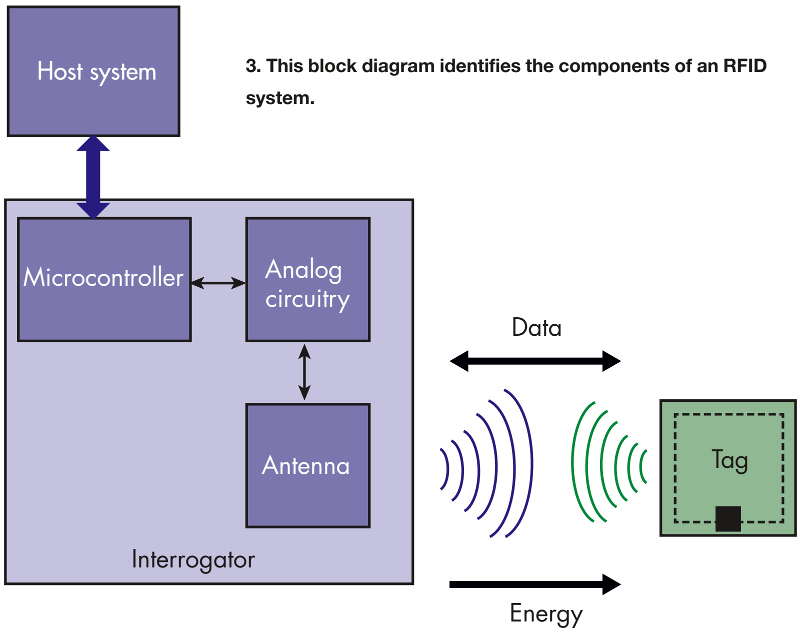
Figures 1 and 2 provide a number of different views of an AR-15 LR. They are typically forged from a lightweight aluminum alloy (7075-T6), but can also be made from steel or a composite material. This current study has focused on metal receivers, since they are more common and more challenging in terms of performing tracking by means of RFID technology.

An initial investigation identified the area covered by the pistol grip (which is typically nonmetal material) as the optimal location for the RFID tag. This area offers sufficient structure to house a small RFID tag flush-mounted on the surface. As such, the pistol grip can be installed without issue or any need to change the firearm assembly procedure. The pistol grip also provides added protection for the RFID tag.

A 4-mm-diameter hole is required to seat the RFID tag. The addition of a 0.8-mm slot provides an improvement in read range, but the RFID tag will also function adequately without it. Further testing is being undertaken to determine if the addition of a 4-mm-diameter hole will degrade the mechanical integrity of the mechanism when subjected to shock, vibration, and variations in temperature.

The tags used with these AR-15 receivers conform to the ISO15693/ISO18000-3 (mode 1) standard for operation in the 13.56-MHz frequency band. The standard specifies passive tags that may only become active if placed in an RF field. As a result, these passive tags do not require a dedicated battery within the firearm.

The RFID tags are powered from the RF field generated by the external electronic devices (the interrogator/reader) generating the RF field and designed to communicate with (read) the tag. Tags designed to this standard are "vicinity devices" and have a limited read range of approximately 1 m depending on their



3. This block diagram identifies the components of an RFID system.

4. One application for RFID tags involves stent tracking in hospital cardiac catheter laboratories.

5. This is a midrange reader with a 125-mm IA.

6. This AR-14 firearm is shown positioned over an IA.

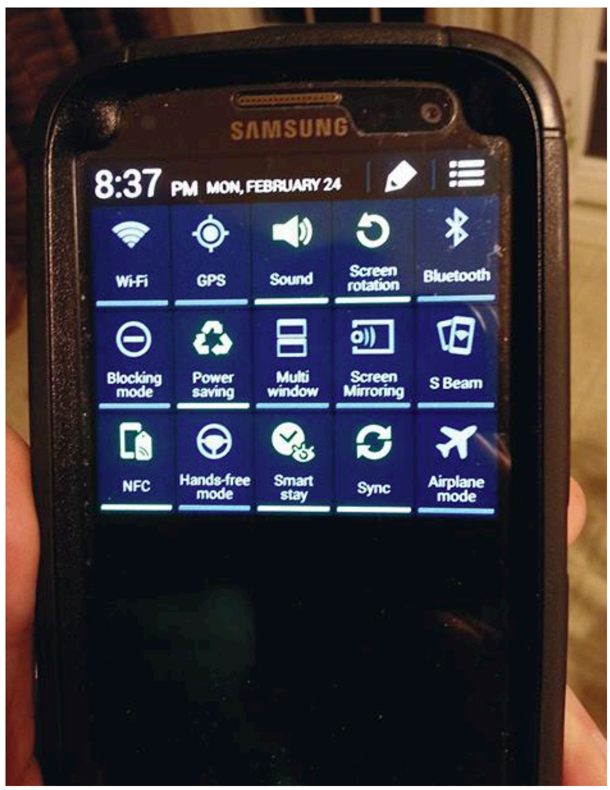
size and the size and power output from the reader antenna, which is commonly referred to as the interrogator antenna (IA). *Figure 3* shows a system block diagram.[1] RFID systems using this standard have been used successfully for inventory tracking of high-value clinical products such as implantable cardiac defibrillators (ICDs) and stents *(Fig. 4)*.[2]

RF TESTING

Numerous readers and IA were studied as part of this project to use RFID tags for firearm tracking. Reader power outputs ranged from 100 mW to 4 W and IAs with 20 to 300 mm diameters were investigated. Read ranges with consistent results varied from 30 to 75 mm depending on the reader/IA configuration. Cellular telephones with near-field-communications (NFC) functionality were found to perform well in reading smaller RFID tags. NFC is a standards-based type of wireless communications that enables the exchange of data between devices over a distance of about 5 cm.

Measurements for this study were made using both an industry-standard mid-range reader (Feig model MR101 with 1-W output) with a 125- × 125-mm^2 IA *(Figs. 5 and 6)* and a Samsung Galaxy S3 cellular telephone *(Fig. 7)*. The use of cellphone technology added a great deal of functionality, such as Global Positioning System (GPS) and emergency calling, to practical applications involving firearms.

Conventional RFID tags *(Fig. 8)* were also investigated and were not found to function well when mounted directly



7. The Samsung Galaxy III is typical of modern smart cellphones, running one of its many applications.

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8. Conventional RFID tags can be supplied in extremely small sizes for unobtrusive attachment to the metal surfaces of firearms.

over metal. Configurations were fabricated with a shallow cavity below the tag that resulted in reasonable read performance, but the tags were not robust from an environmental point of view.

In time, it's thought that rugged RFID tags will be available in various formats, and high performance for reasonable cost will dictate their use. The concept of a single 4-mm through hole as the only modification to the LR appeared to be less obtrusive than the other configurations that were investigated. The on-metal tags have also been tested in accordance with the shock and humidity requirements specified by MIL-STD-202 Equipment Qualification testing.

Initial testing required, as a minimum, the capability to reliably read both the tag UID and programmable memory as well as to write and store the programmable memory. Both read and write tests were performed repeatedly with both readers over a quantity of five tags and various distances and orientations. In all testing, it was found that reliable performance can be achieved within a 50-mm range as long as the IA plane was reasonably parallel with that of the tag.

Near-field RFID relies on inductive coupling; the orientation of the magnetic fields must align to achieve optimal read range performance. In order for the tag to become active, the voltage induced by the reader and IA RF field (V_{tag}) must be sufficient to achieve the minimum level requirements of the RFID chip embedded on the RFID tag. The level of V_{tag} is a function of the tag size/orientation. The magnitude of the magnetic field strength for an ideal loop may be expressed by:[3]

$$V_{tag} = 2\pi f_0 NQB(S\cos\alpha) \qquad (1)$$

where N = the number of windings in the tag coil; Q = the tag quality factor; B = the magnetic field strength; S = the area of the tag coil; and α = the tag orientation angle.

The magnetic field strength, B, is generated by a circular IA and may be expressed by:

$$B = \mu_0 Ina^2/2r^3 \quad (2)$$

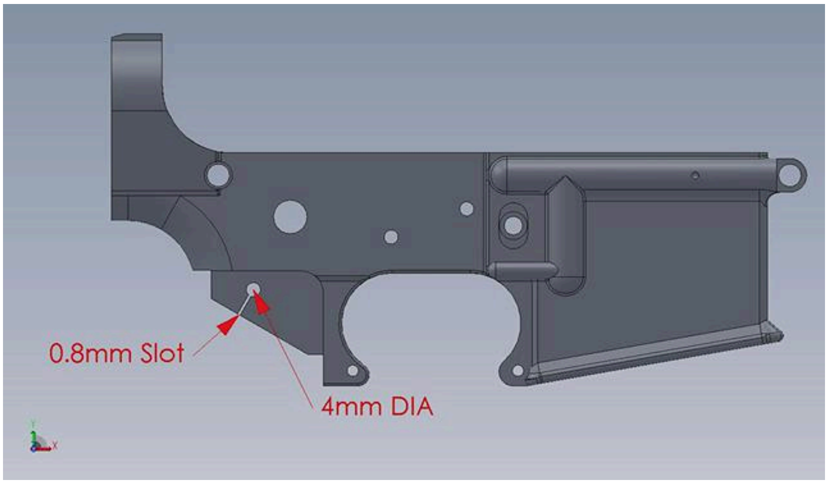
where I = the IA coil current; N = the number of windings in the IA coil; a = the radius of the IA coil; μ_0 = the permeability of free space; and r = the distance from the IA.

RFID has proven to be an effective technology in a laboratory environment, but is still gaining momentum for use in real-world applications. For successful use in many applications, it is essential to read an RFID tag with a sufficient degree of confidence. Some RFID systems currently in use deliver 100% read accuracy.[4] Once the RF functionality is achieved for optimal RFID performance, RFID technology can be used for many practical applications.

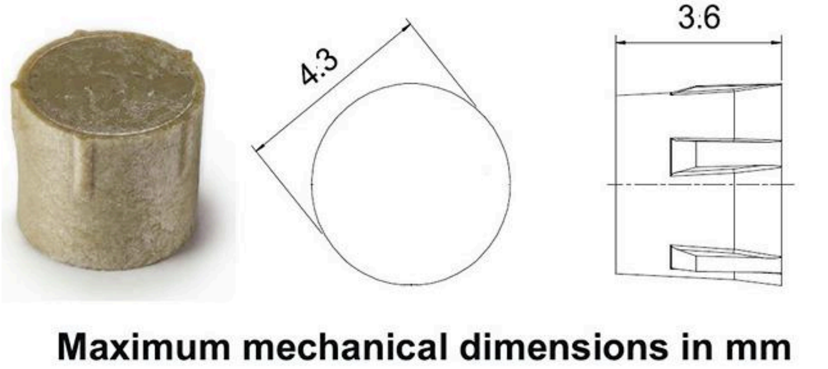
From the reliability of the read/write performance measured and MIL-STD testing, there's a high degree of confidence that the proposed application will work in tracking firearm components. It's worth noting that RFID technology, which has been well adopted by the cellphone industry, has become very affordable over the past few years and offers low-cost integration into almost any application, as will be explained by means of some examples.

To verify functionality in a practical environment, a Ruger AR556 was modified *(Fig. 9)* and fitted with an RFID tag *(Fig. 10)*. To date, over 1000 rounds of NATO 5.56- × 45-mm, 55 grain full-metal-jacket (FMJ) ammunition have been fired through the firearm with the use of a single RFID tag. Most tests consisted of firing 100 rounds per day, with 200 rounds fired in one day, mostly in rapid-fire mode. Rounds were fired at various temperatures (+20 to +95°F) in an attempt to test the robustness of the RFID tags.

Over the course of the testing, the RFID read/write performance was recorded, without any failures or degradation in performance. Failure was identified as the inability to read an RFID tag's UID and read/write programming information, while degradation was identified as a reduction in the read range of the tag.



9. Shown is a modified AR-15 LR.



10. These are the dimensions of a typical modern RFID tag.

PROPOSED LAW

In the United States, New Jersey passed the Childproof Handgun Bill into state law on December 23, 2002. This proposed legislation will eventually require that all firearms sold in New Jersey will have some form of mechanism to prevent unauthorized use of a firearm. The law will take effect three years after this type of smart gun is approved by the state. A bill currently in the New Jersey Legislative Assembly, No. 1016, State of New Jersey, is an act concerning personalized handguns that's meant to revise various parts of the statutory law according to the following specifications:

A handgun shall be reasonably resistant to being fired by anyone other than its authorized user as defined by New Jersey Statutory 2C:39-1.

The personalized technology shall be incorporated into the design of the handgun and shall be a permanent, non-removable part of the handgun and a device or object that is required for the authorized user to fire the handgun.

The personalized handgun shall not be manufactured to permit personalized characteristics of the firearm to be deactivated.

The personalized handgun shall meet any other reliability standards generally used in the industry for other commercially available handguns.

This NJ bill also specifically identifies RFID as a possible technology for limiting a handgun's operational use.

One proposed method for ensuring compliance to the proposed legislation is to associate the authorized user of a firearm to the RFID tag embedded within the firearm and an external key fob or cellular telephone. A key fob is a small electronic device typically used in place of a key (as to unlock a door or start a vehicle), or to remotely initiate the action of another device. A cellphone application programmed with the UID of the firearm can be used to trigger the unlock mechanism within the firearm. Since cellphones can read and write to RFID tags, additional equipment external to the firearm would not be required.

As discussed earlier, the receiver is commonly the only federally regulated component of the firearm and will remain with the assembly throughout its life span. Since other components can be replaced, it's logical for the receiver to store the history of the firearm. Records such as rounds fired, disassembly, cleaning, and inspection criteria are most common data that would be stored in such a location. The bore, firing pin, bolt face, gas ring, and gas key must routinely be inspected and data from reports could be recorded into the tag.

For those law-enforcement officers who are handed an anonymous firearm from storage, it's prudent to know its most recent history or to update its usage prior to returning the firearm to storage. Performing a 10-second scan of the weapon's history prior to engagement into an emergency situation could possibly screen out defective or questionable weapons. Cellphone applications with a simple checklist and red-flag indicator are currently being developed that provide a government officer with practical real-time feedback and a reporting mechanism that's designed to require less than one minute to complete.

The AR-15 is known to "run dirty." Unlike other gas-activated weapons, the AR-15 valves the gas back into the action where, with every firing of the weapon, hot, carbon-laden gases can be produced that can foul the firearm's mechanisms. A day of target practice commonly results in a soot-laden, oily contamination that requires some effort to clean.

A firearm used in an anonymous, unknown fashion may require significant routine maintenance that can be effectively tracked and recorded by means of RFID technology. Addition of onboard electronics and sensors can enable the automated updating of the firearm's use and history into the memory portion of the RFID IC. An example of such functionality is the employment of accelerometers to sense the recoil used to record the number of rounds fired.

Federal law (the Gun Control Act of 1968) regulates that all newly manufactured firearms produced by licensed manufacturers in the United States and imported into the country bear a serial number. For this reason, it's common to associate the embedded RFID tag's UID with the serial number of the firearm. This allows recovery of the serial number, assuming that the firearm's serial number has not been obliterated or altered in any way. It would only be practical if the RFID tag were hidden and disguised.

The RFID tag discussed previously *(Fig. 10, again)* has been sealed into the receiver using black epoxy. Such attachment makes it difficult to locate on the firearm, and would require the use of tools to destroy the RFID tag.

Placing cellphone/RFID technology into the holsters of law-enforcement officers has also been under evaluation for tracking firearm use by those law-enforcement officers. This application triggers a response upon the removal of the weapon from the holster. Low-cost, unobtrusive cellphone circuitry employing NFC and GPS technologies is built into the holster.

When an officer draws his or her weapon, the RFID IC senses this action, which triggers a response to emergency services with the time of the withdrawal of the weapon, the shield number, and the GPS location of the officer withdrawing the weapon. Updating of the location can continue until the officer re-holsters the weapon. This provides emergency services or the officers themselves with the ability to monitor multiple law-enforcement officers and makes it possible to coordinate in-field activities of officers and/or reduce the chance of injuries in a cross-fire situation.

In short, as has been shown though practical measurements, the use of miniature, low-cost RFID tags on metal can be effective for applications involving tracking of firearms, such as AR15, M4, and M16 firearms. Such applications will employ low-cost cellular telephone technology, such as NFC and GPS, that's unobtrusive and presents significant added value to the firearms in addition to RFID functionality.

The RFID tags evaluated for these applications have shown they meet MIL-STD requirements, providing a high degree of confidence that they can maintain high performance while withstanding environmental stress. This successful implementation of RFID on metal surfaces for tracking firearms is a first step in addressing some of the new laws being proposed for tracking firearms. mw

THE AUTHOR would like to thank Stephen Rogg of Shawsheen Firearms for his help in keeping us safe at the firing range.

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NB-IoT DEVELOPMENT Receives a Hand from Simulation

The massive amount of expected Internet of Things (IoT) devices will require heavy support from existing wireless networks. Narrowband-IoT (NB- IoT) is a wireless communications technology that enables a wide range of devices and services to be connected using cellular bands. In the application note, "Simulation Test Bench for NB-IoT Products," National Instruments presents an overview of NB-IoT requirements and the challenges associated with component design and simulation. The application note demonstrates how the Visual System Simulator (VSS) software can be used for NB-IoT design and analysis by presenting example projects.

The application note explains that NB-IoT will enable operators to provide wireless capability to developing businesses, such as smart metering and tracking. Smart cities and eHealth infrastructure are two industry opportunities that NB-IoT will create, according to the note. With NB-IoT, many devices will be efficiently connected using already established mobile networks and be able to handle small amounts of moderately infrequent two-way data securely and reliably. Furthermore, the NB-IoT standard utilizes a 180-kHz user-equipment (UE) RF bandwidth for both downlinks and uplinks.

AWR Corp.,
1960 E. Grand Ave.
Suite 430,
El Segundo, CA 90245;
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NB-IoT is different than cellular technologies, which need large bandwidths along with high data rates and low latency at the expense of lower device battery lifetimes. Rather, NB-IoT requires robust data transmission with significantly lower data rates, long-range coverage, and long device battery lifetimes. Cost in comparison to mobile devices is also mentioned, as many NB-IoT use cases demand a low device price.

A VSS project presented in the note demonstrates operation of an NB-IoT system inside an LTE signal band. In this example, the NB-IoT signal is placed in an unused resource block (RB) within the LTE band. It's pointed out that the simulation of NB-IoT and LTE coexistence in different operating scenarios supports companies that are involved with 3rd Generation Partnership Project (3GPP) standardization and product development. Also shown is an illustration of narrowband physical uplink shared channel (NPUSCH) encoding. Another example demonstrates NB-IoT operation in the guard band of an LTE signal.

DIG DEEPER into 5G NR with Simulation

THE 3RD GENERATION PARTNERSHIP PROJECT (3GPP) released the non-standalone (NSA) 5G New Radio (NR) specification last December. The NSA specification is associated with LTE/NR dual connectivity (DC). NSA deployment requires more complex hardware implementations to allow for simultaneous connections with both LTE and NR networks.

In the white paper, "Simulation for 5G New Radio System Design and Verification," Keysight Technologies discusses some of the common technical challenges associated with 5G NR. Such challenges arise due to LTE/NR DC coexistence issues, as well as implementing millimeter-wave (mmWave) components in mobile devices.

Initially, the paper discusses the global spectrum landscape for 4G and 5G, explaining that the specific 5G spectrum bands zero in on mid-band frequencies (3.3 to 4.2 GHz) for longer distance service and high-band frequencies (24.25 to 29.5 GHz) for faster data speeds. The 3GPP specification defines different frequency ranges (FR), with the FR1 designator corresponding to frequencies between 0.45 and 6 GHz, and FR2 referring to operating bands between 24.25 GHz and 52.6 GHz.

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Differences exist between 5G NR and 4G LTE that must be addressed in RF design, according to the paper. It also states that creating thousands of test cases to support increasing LTE frequency bands, defining various carrier-aggregation (CA) scenarios, and calculating intermodulation-distortion (IMD) and harmonics with different combinations of aggressor and victim bands all require a large amount of simulation and test time.

Included in the paper is a sub-6-GHz DC IMD case study. A behavioral model of a DC-enabled RF front end (RFFE) is shown; simulation results reveal the created IMD signals. Following that discussion, a mmWave front-end architecture is presented.

Over-the-air (OTA) simulation is also discussed, first getting into the configuration of an OTA test system before explaining the importance of performing simulations of an OTA environment. This simulation makes it possible to model the individual OTA building blocks, enabling the designer to divide the key functional blocks and better perform a root-cause analysis. An over-the-air (OTA) analysis example is provided as well.

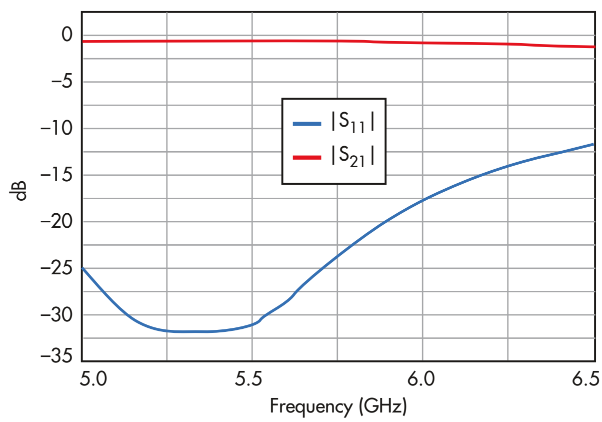
CHRIS DeMARTINO | Technical Editor

Brushing Up on Network Analyzer Fundamentals

Whether measuring production components or engineering prototypes, today's versatile network analyzers have become essential tools in the designer's toolbox.

Network analyzers are indispensable test instruments in the RF/microwave industry. Their measurement capabilities allow them to characterize a wide range of devices, components, and systems. Many components—both passive and active—are commonly measured with a network analyzer, including amplifiers, filters, attenuators, switches, and many others.

Network analyzers are relied upon heavily for manufacturing production testing. A component's datasheet typically contains a significant amount of information obtained from a network analyzer. In addition, network analyzers are used for research and development purposes. They can be used to measure engineering prototypes, thus allowing engineers to optimize performance characteristics like gain flatness and return loss.



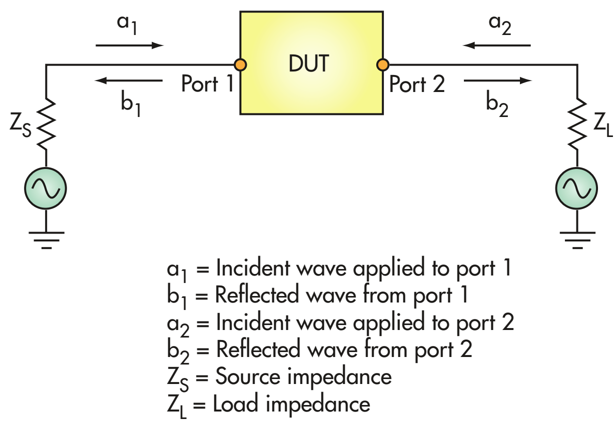
1. This plot is a depiction of a network analyzer measurement.

WHAT NETWORK ANALYZERS DO

Network analyzers can measure and display a device under test's (DUT) magnitude and phase information across a frequency range. A generic illustration of a network analyzer plot is shown in *Figure 1*. In essence, a network analyzer characterizes a DUT in terms of scattering parameters, or S-parameters.

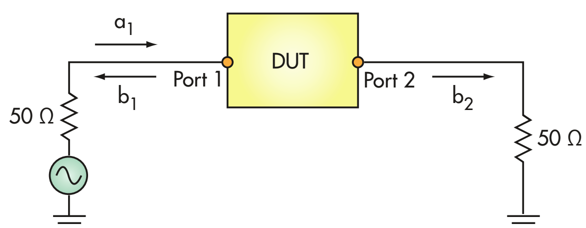
S-parameters are used to characterize performance at RF and microwave frequencies in terms of incident and reflected waves. S-parameters are vector quantities, meaning they contain both magnitude and phase information. A scalar network analyzer (SNA) can only measure magnitude, while a vector network analyzer (VNA) can measure both magnitude and phase. Each of these will be discussed in more detail later.

Figure 2 shows an illustration of a two-port network. 50-Ω impedances are typical of most RF/microwave applications. Hence, Z_S and Z_L in *Fig. 2* would generally be 50 Ω. Cable-television (CATV) applications are the main exception, as they operate in a 75-Ω environment.



2. Shown is a two-port network.

Figure 3 is based on the network shown in *Fig. 2*. Here, Z_S and Z_L are equal to 50 Ω. Port 2 of the DUT is terminated in a 50-Ω load, thus setting a_2 to be equal to zero.



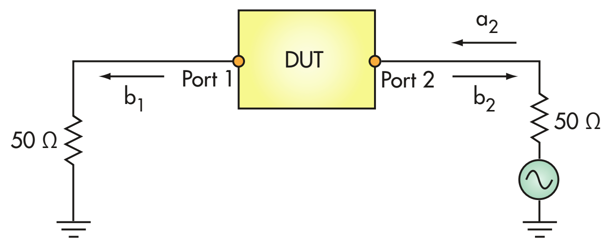
3. In this figure, an incident wave, a_1, is applied to the DUT.

In *Fig. 3*, a_1 is applied to Port 1 of the DUT. A portion of this incident wave is transmitted through the DUT and exits through Port 2, thereby resulting in b_2. A portion of the incident wave is also reflected back to the source, thereby resulting in b_1. Now, two S-parameters, S_{11} and S_{21}, can be mathematically defined as follows:

$$S_{11} := \left.\frac{b_1}{a_1}\right|_{a_2 = 0} \qquad S_{21} := \left.\frac{b_2}{a_1}\right|_{a_2 = 0}$$

Figure 4 is also based on the network shown in *Fig. 2*. Here, Port 1 of the DUT is terminated in a 50-Ω load, thus setting a_1 to be equal to zero.

In *Fig. 4*, a_2 is now applied to Port 2 of the DUT. A portion of this incident wave is transmitted through the DUT and exits



4. Here, an incident wave, a_2, is applied to the DUT.

through Port 1, thereby resulting in b_1. A portion of the incident wave is also reflected, thereby resulting in b_2. Now, the two remaining S-parameters, S_{12} and S_{22}, can be mathematically defined as follows:

$$S_{12} := \left.\frac{b_1}{a_2}\right|_{a_1 = 0} \qquad S_{22} := \left.\frac{b_2}{a_2}\right|_{a_1 = 0}$$

A two-port network therefore has four S-parameter elements: S_{11}, S_{21}, S_{12}, and S_{22}. S_{11} and S_{22} are known as reflection coefficients. S_{21} and S_{12} are known as transmission coefficients. Furthermore, a network can be defined in matrix form, known as an S-parameter matrix. The S-parameter matrix of the two-port network discussed previously is shown as:

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

As stated earlier, S-parameters contain both magnitude and phase information. Magnitude is typically expressed in decibels (dB). This is mathematically defined as:

$$S_{11}(\text{dB}): 20 \log_{10} |S_{11}|$$

$$S_{12}(\text{dB}): 20 \log_{10} |S_{12}|$$

$$S_{21}(\text{dB}): 20 \log_{10} |S_{21}|$$

$$S_{22}(\text{dB}): 20 \log_{10} |S_{22}|$$

The dB representations of S_{11} and S_{22} are known as return loss, which is the difference in dB between the reflected signal and the incident signal. Thus, a return loss of −15 dB means that the reflected signal is 15 dB lower in magnitude than the incident signal. Return loss is commonly expressed as a positive value, so a return loss of −15 dB is often expressed as just simply 15 dB.

The magnitude element of S_{21} is known as gain or insertion loss, depending on whether the DUT is active or passive. In other words, an active device—such as an amplifier—has gain because it increases the magnitude of an input signal. A passive component like a filter does not have gain, meaning the output signal is smaller in magnitude than the input signal. In this case, S_{21} is referred to as insertion loss. S_{12} defines transmission in the reverse direction. Thus, it's known as reverse gain or reverse transmission.

It's often important to characterize phase along with magnitude. As discussed already, when an incident signal is applied to a DUT, a portion of that signal is transmitted. The transmitted signal that exits the DUT differs not only in magnitude from the incident signal, but also in phase. Hence, S_{21} and S_{12} also describe the phase difference in degrees between a transmitted signal and an incident signal. A linear phase response over frequency is desirable—deviating from one can cause distortion.

Group delay is the transit time of a signal as it passes through a DUT. It's mathematically defined as the negative of the derivative of phase response with respect to frequency, meaning that it quantifies phase linearity. Thus, a flat group delay means the phase response is linear. Network analyzers are commonly used to measure the group delay of components, such as filters.

The two-port model that has been discussed represents a component with two ports. However, many components have more than just two ports. *Figure 5* shows an illustration of an N-port network. The DUT here could possibly be a power divider or some other component with multiple ports. The S-parameter matrix of this network is:

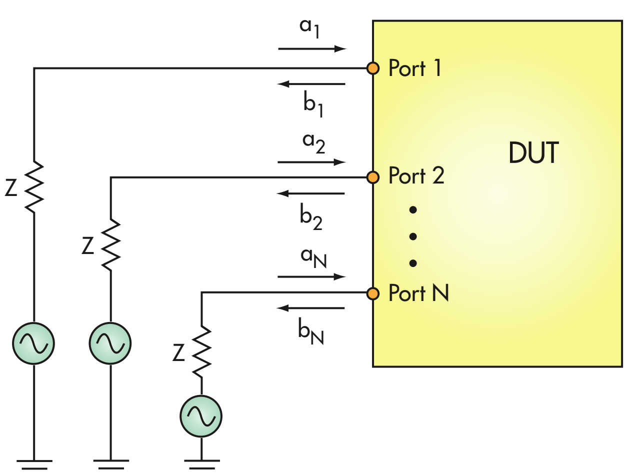
$$\begin{bmatrix} b_1 \\ \bullet \\ \bullet \\ b_n \end{bmatrix} = \begin{bmatrix} S_{11} & \bullet & \bullet & S_{1n} \\ \bullet & \bullet & \bullet & \bullet \\ \bullet & \bullet & \bullet & \bullet \\ S_{n1} & \bullet & \bullet & S_{nn} \end{bmatrix} \begin{bmatrix} a_1 \\ \bullet \\ \bullet \\ a_n \end{bmatrix}$$

HOW NETWORK ANALYZERS WORK

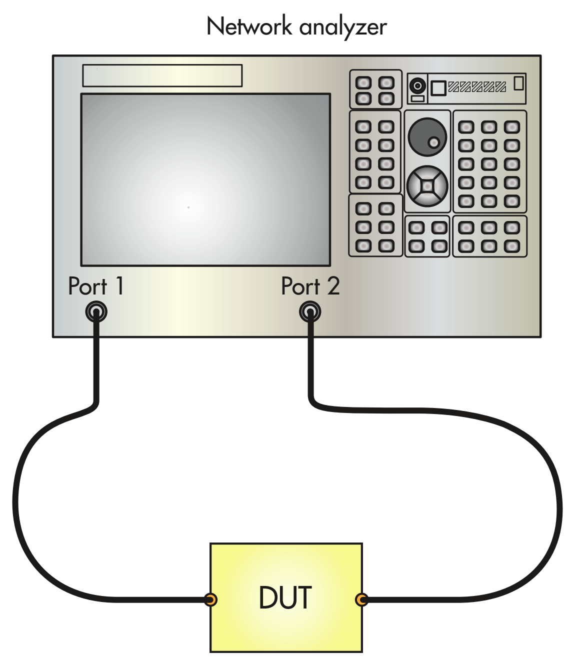
The fundamental purpose of a network analyzer is to measure S-parameters. A network analyzer can be classified as either a VNA or an SNA. VNAs have become more widely used in recent years. However, let's first discuss SNAs.

SNAs can only measure magnitude. They do not have the capability to perform phase measurements. SNAs perform transmission measurements by means of a diode detector, which converts an RF signal to a dc voltage. This dc voltage is proportional to the magnitude of the RF signal. Unfortunately, this process does not take phase information into account. Return loss measurements can be achieved by means of a directional bridge.

VNAs are much more powerful than SNAs, as they can measure both magnitude and phase. *Figure 6* is an illustra-



5. This figure shows a network with N ports.



6. Shown is a vector network analyzer (VNA) measuring a two-port component.

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SNAs can only measure magnitude. They do not have the capability to perform phase measurements. SNAs perform transmission measurements by means of a diode detector, which converts an RF signal to a dc voltage. This dc voltage is proportional to the magnitude of the RF signal.

tion of a VNA being used to measure a two-port component, such as a filter or amplifier. The input of the DUT is connected to the end of a cable that's attached to Port 1 of the VNA. The DUT's output is connected to the end of a cable that is attached to Port 2 of the VNA. The DUT shown in *Fig. 6* essentially represents the DUT shown in *Fig. 2*.

In *Fig. 6*, the VNA contains an RF source, which generates signals over the frequency range of interest. These signals exit through Port 1 and are applied to the DUT. When a signal at any frequency is applied to the DUT, a portion of that signal is transmitted through the DUT to Port 2 of the VNA. Another portion is reflected back to Port 1. The user can then see S_{21} or S_{11} measurements on the VNA's display.

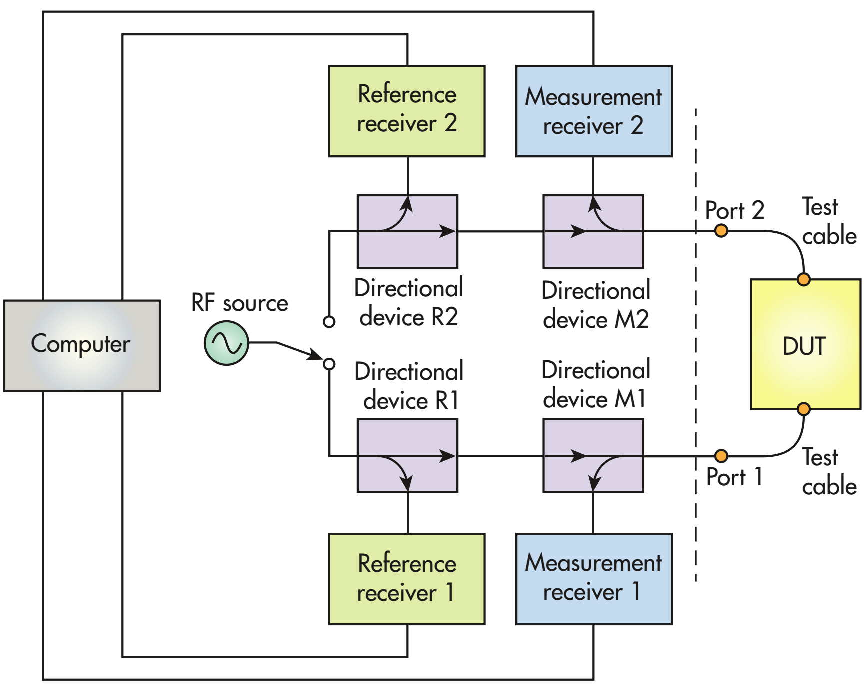
To measure S_{22} or S_{12}, the VNA generates signals that exits through Port 2 and are applied to the DUT. A portion of a signal at any frequency applied to the DUT now transmits through the DUT to Port 1 of the VNA. Another portion is reflected back to Port 2. Now, the user can see S_{12} or S_{22} measurements on the display.

The VNA's architecture can now be examined to understand how these measurements are achieved. *Figure 7* shows a general block diagram of a VNA with two test ports. (It should be noted that *Fig. 7* shows a general VNA architecture. Additional variations are possible, but the general concept remains.) The signals generated by the VNA's RF source enter a switch, which routes the signal toward either Port 1 or Port 2.

To measure S_{11} or S_{21}, the switch would route the signal toward Port 1. The signal first enters a directional device, shown as Directional Device R1 in *Fig. 7*. This directional device could be a directional coupler or bridge. A power divider could also be used here. The purpose of this device is to direct a portion of the input signal to a reference receiver, shown as Reference Receiver 1. Once the signal enters this reference receiver, it's downconverted and ultimately processed.

The signal that passes through Directional Device R1 then passes through another directional device, shown as Directional Device M1 in *Fig. 7,* before arriving at the DUT. When the signal does arrive at the DUT, a portion is reflected back to Port 1 of the VNA and reenters Directional Device M1. This device now directs a portion of the reflected signal to a measurement receiver, shown as Measurement Receiver 1. Next, this signal is downconverted and processed. The VNA can then compare the data obtained from Measurement Receiver 1 with the data obtained from Reference Receiver 1. This process summarizes how S_{11} is measured.

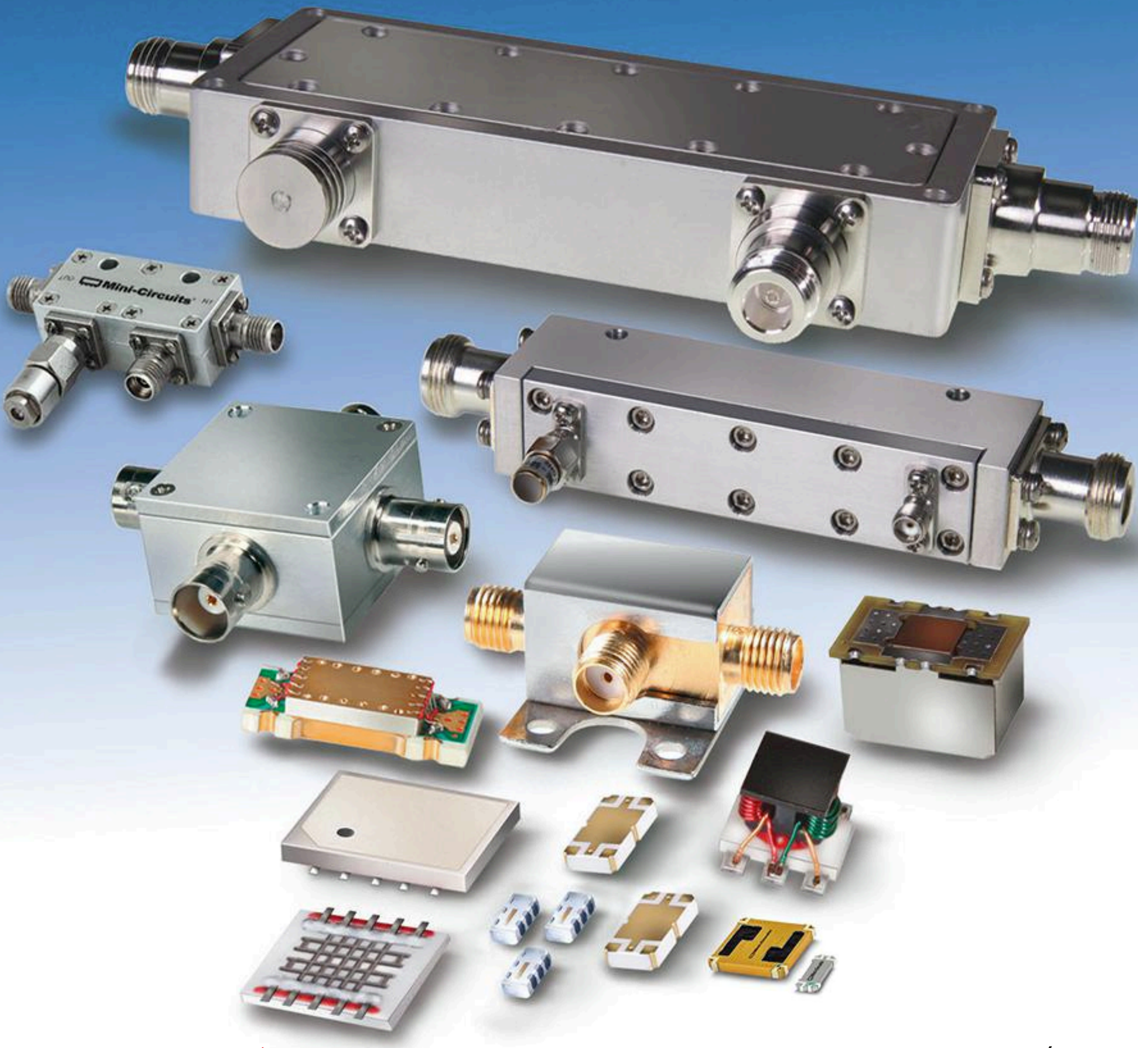
The signal applied to the DUT also results in a transmitted signal, which exits the DUT and enters Port 2 of the VNA. This transmitted signal enters another directional device, shown as Directional Device M2 in *Fig. 7*. This device directs a portion of the signal to another measurement receiver, shown as Measurement Receiver 2. This signal is subsequently down-



7. Here's a simplified block diagram of a VNA with two test ports.

Directional / Bi-Directional

COUPLERS



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As previously stated, many components have more than just two ports. Many VNAs also have more than two test ports to conveniently measure such components. For example, four measurement receivers and four reference receivers could be used to build a four-port VNA, allowing a four-port component to be easily measured.

converted and processed. Now, the VNA can compare the data obtained from Measurement Receiver 2 with the data obtained from Reference Receiver 1. This process summarizes how S_{21} is measured.

To measure S_{22} or S_{12}, the switch would route the signal to Port 2. The same process occurs in the opposite direction: The signal first enters Directional Device R2 in *Fig. 7* which directs a portion of the signal to Reference Receiver 2. After entering this reference receiver, the signal is downconverted and processed.

The signal that passes through Directional Device R2 then passes through Directional Device M2 on its way toward the DUT. After arriving at the DUT, a portion of the signal is reflected back to Port 2 of the VNA and reenters Directional Device M2. Now, a portion of this reflected signal is directed to Measurement Receiver 2. Afterward, this signal is downconverted and processed. The data obtained from Measurement Receiver 2 can then be compared with the data obtained from Reference Receiver 2, thus summarizing the S_{22} measurement process.

The signal that's transmitted through the DUT enters Port 1 of the VNA. This transmitted signal enters Directional Device M1 in *Fig. 7*, which directs a portion of the signal to Measurement Receiver 1. This signal is likewise downconverted and processed. The data obtained from Measurement Receiver 1 can now be compared with the data obtained from Reference Receiver 2, thus summarizing the S_{12} measurement process.

As previously stated, many components have more than just two ports. Many VNAs also have more than two test ports to conveniently measure such components. For example, four measurement receivers and four reference receivers could be used to build a four-port VNA, allowing a four-port component to be easily measured.

NETWORK ANALYZER SPECIFICATIONS

Several important specifications define a network analyzer:

Frequency range: This is the main specification. A network analyzer's frequency range defines the minimum and maximum frequencies it can measure.

Dynamic range: This defines the range of power that the network analyzer can measure.

Number of test ports: A network analyzer can have two, four, or more test ports.

Measurement speed: This is the time required to perform measurements across a range of frequencies. mw

JACK BROWNE | Technical Contributor

Compact Synthesizer Reaches Low-Phase-Noise Levels

For applications requiring smaller size and lighter weight, this PLL frequency synthesizer does the trick in a compact enclosure that operates from 10 MHz to 15 GHz.

Miniaturization has become an increasingly important requirement in many high-frequency systems, even though the complexity of some components, such as frequency synthesizers, can be challenging to fit into a compact housing. Meeting that challenge for small synthesizers in a big way, the 5015 frequency-synthesizer module from Valon Technology tunes from 10 MHz to 15 GHz with low phase noise and spurious products. It also offers fast tuning speed in a compact housing measuring just 3.2 × 4.3 × 0.485 in.

Typical phase noise for the module is −114 dBc/Hz offset 1 kHz from a 1-GHz carrier and −138 dBc/Hz offset 1 MHz from the same carrier. The phase noise, as expected, is somewhat higher at higher frequencies, but still impressive, with −94 dBc/Hz offset 1 kHz from 10-GHz carrier and −120 dBc/Hz offset 1 MHz from the 10-GHz carrier. Spurious products are −60 dBc or less. Harmonics are typically −12 dBc.

The model 5015 frequency synthesizer module (*Fig. 1*) operates on a wide input voltage range of about 5 to 15 V dc, with about 6 W power consumption, thanks to an efficient, low-noise switching preregulator. The synthesizer is designed with multiple phase-locked loops (PLLs) for low phase noise. It tunes in frequency increments of 1 Hz to 4 GHz and in increments of 10 Hz at frequencies higher than 4 GHz. It locks to a new frequency in less than 100 μs.

1. This compact, lightweight frequency-synthesizer module tunes from 10 MHz to 15 GHz and measures only 3.2 × 4.3 × 0.485 in.

2. The 5015 frequency-synthesizer module can be operated via a number of different interfaces, including Ethernet and USB.

The 5015 offers a calibrated output power range of −20 to +13 dBm, which can be set in 0.1-dB steps, with output-power accuracy of ±0.9 dB or better. It has an output-power range of −30 dBm to better than +10 dBm from 10 to 100 MHz, better than +15 dBm from 1 to 6 GHz, and better than +13 dBm from 6 to 15 GHz.

An internal temperature-compensated crystal oscillator (TCXO) provides ±2-ppm stability over a temperature range of −20 to +70°C. In addition, an SMA input connector will accept reference signals from any external clock from 5 to 100 MHz in 0.2-MHz increments. The 5015 can be operated with an external reference source that supplies at least −10 dBm power.

The synthesizer module can be controlled by means of Ethernet (*Fig. 2*), transistor-to-transistor-logic (TTL) serial, and Universal Serial Bus (USB) interfaces, with the firm offering a graphical user interface (GUI) for use with the USB connection. The device does not draw power from the USB interface, but can be powered by any 5- to 15-V dc source or an optional PS6V-1 power-supply kit, available from Valon. In addition, the Eth-01 Ethernet Adapter is also available as an accessory. It allows the frequency synthesizer to be remotely mounted as far as 8 in. from the location of the Ethernet connector, for use in bulkhead panel-mount applications.

The 5015 exhibits output return loss of better than 6 dB from 10 to 100 MHz, 10 dB from 50 MHz to 10 GHz, and 6 dB from 10 to 15 GHz. It weighs just 0.37 lbs, (165 g) with SMA female output connectors, and can be operated at a case temperature of 0 to +60°C. mw

VALON TECHNOLOGY LLC, 750 Hillcrest Dr., Redwood City, CA 94062; (650) 367-1059, E-mail: sales@valontechnolog.com, www.valonrf.com.

JACK BROWNE | Technical Contributor

High-Power Transistors Fit Standard Plastic Packages

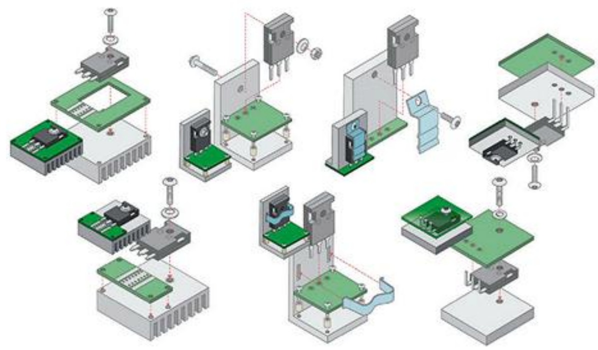
These two LDMOS power transistors sacrifice nothing in terms of performance by using plastic packages, which offer a great deal of flexibility in mounting to a PCB.

If high-power RF transistors are usually protected by fairly costly ceramic packages, to protect the semiconductor chips inside as much from the environment as from thermal buildup. However, several high-power RF transistors from NXP Semiconductors include a 100-W device in a TO-220 housing and a 300-W device in a TO-247 housing, with both packages being standard plastic housings, for handling ease and simplicity (*Fig. 1*). The transistors are supported by reference designs that demonstrate their performance from 1.8 through 250.0 MHz for applications from HF through VHF.

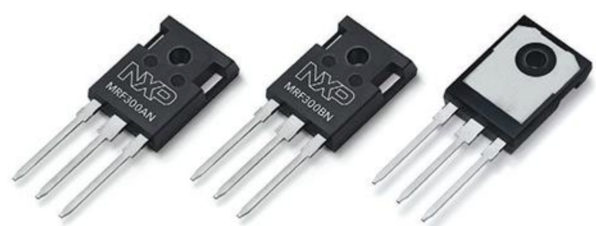
The power transistors are based on laterally diffused metal-oxide-semiconductor (LDMOS) device technology, which is backed in production by well-established assembly procedures. In contrast to most standard plastic packages used for high-power RF transistors, which must be attached to a printed-circuit board (PCB) by means of a precise solder reflow process, these plastic-packaged power transistors can be added to a PCB without exotic or expensive techniques. They can be assembled to a PCB using standard through-hole technology to reduce cost. The use of standard packaging enables vertical mounting on a circuit, which helps usher in new and creative ways to achieve proper heatsinking.

The two power transistors are well-suited for commercial communications, broadcast, and industrial-scientific-medical (ISM) band applications. They are the models MRF101AN, which provides 100 W output power from a plastic TO-220 package, and MRF300AN, which delivers 300 W output power from a plastic TO-247 package. In fact, the MRF300AN has been tested as part of a reference circuit design to provide 330 W CW output power at 40.68 MHz, with 28-dB gain and 79% efficiency (*Fig. 2*). It's designed to withstand impedance mismatches as severe as the equivalent of a 65.0:1 VSWR.

Compact 2- × 3-in. (5.1 × 7.1 cm) power block reference designs based on low-cost PCB material are available to demonstrate the capabilities of the plastic-packaged LDMOS transistors at standard application frequencies, such as 27, 40.68, 81.36, and 230 MHz. For example, by changing some coils and discrete components and without changing the PCB layout, the 40.68-MHz layout can be modified for frequencies from 1.8 to 250.0 MHz to enable quick design cycles for high-frequency circuits, such as power amplifiers. With their mounting flexibility in such plastic packages, these transistors are expected to open some new markets, e.g., high-frequency switching power supplies.



1. This collage of different mounting examples shows the flexibility of having the MRF101AN and MRF300AN supplied in standard, plastic packages.



2. The high-power MRF300AN LDMOS transistor delivers more than 300 W pulsed or CW output power at ISM-band frequencies with high gain.

The transistors are available in a choice of plastic-packaged configurations. For example, the MRF101BN has the reverse pin-out pattern as the MRF101AN to enable easy push-pull power layouts with the two packaged transistors. The devices are part of NXP's Product Longevity Program which guarantees availability for 15 years.

"RF power is moving increasingly into new applications, where the requirements for ease of use, high performance, and versatility are essential," says Pierre Piel, senior director and general manager for multiple-market RF power at NXP. "We continue our mission to ease the use of RF power by delivering solutions that minimize design requirements, reduce time to market, and simplify the supply chain for our customers." mw

NXP SEMICONDUCTORS, High Tech Campus 60 5656 AG Eindhoven, The Netherlands, *www.nxp.com*

JACK BROWNE | Technical Contributor

Pocket-Sized Instrument Packs TDR and Fast-Edge Generator

This low-cost fast-edge pulse generator provides the means to measure PCB dielectric constants and the impedances of cables and interconnections.

Test instruments have traditionally been found in 19-in.-wide equipment racks, weighing too much to easily move about the laboratory or production floor. To combat that, a recent industry trend has been to shrink the size of high-performance test equipment.

One such development is the PerfectPulse Fast Edge Signal Generator from Picotest Corp. It provides square waves with 32-ps rise and fall times and the pulse edges needed to precisely measure things like cable and printed-circuit-board (PCB) transmission-line lengths and impedances, and even the dielectric constant of PCBs and other materials. For all of its capabilities, the PerfectPulse generator is remarkably compact, small enough to fit in a shirt pocket.

The PerfectPulse signal generator (*Fig. 1*) generates pulsed output signals at 50 mV and 50 Ω with no overshoot or undershoot—the kind of square waves that are extremely useful for performing time-domain-reflectometry (TDR) and time-domain-transmission (TDT) measurements utilizing a high-speed, real-time oscilloscope with sufficient bandwidth. The signal generator will be shipped with a 10-GHz power splitter so that the dual test signals can be used for high-performance TDR and TDT measurements on PCBs and PCB signal traces, as well as to measure the lengths of cables and signal traces, plus verify the quality of crimps in cables.

The J2151A PerfectPulse signal generator can be used for oscilloscope probe calibration. The compact signal generator is compatible with all 50-Ω probes, for convenient signal injection and noninvasive stability measurements on circuits. It works with a high-speed probe such as the Picotest model P2100A PDN Probe to measure PCBs on a 1-to-2-GHz real-time oscilloscope (RSO). The one-port P2100A test probe (*Fig. 2*) supports connections to 1.5 GHz with almost no capacitive loading: less than 1-pF capacitance, and typically only 420-fF capacitive loading.

1. The fast rise and fall times of the PerfectPulse signal generator, as shown on this 70000 series oscilloscope from Tektronix, make it suitable for calibrating test probes and for TDR measurements on cables and circuit traces.

For the signal generator, simple single-button operation makes it possible to select different operating frequencies with settings for square waves at 1, 10, and 100 kHz, as well as 1 and 10 MHz, in addition to ground and dc output settings. The signal generator uses a 3.5-mm coaxial connector with its wide bandwidth and durability for added reliability. The connector type has been found to support more mating cycles than either 2.92-mm or SMA connectors.

The J2151A PerfectPulse signal generator produces output pulses of –500 mV at 50 Ω, trimmed to 1%. The signal generator is USB-powered, drawing typical 100-mA operating current. It can be used with a battery or a USB charger as a power supply. Included is an evaluation board with different reference circuit traces for TDR testing. P&A: $3500; stock. mw

2. The one-port P2100A test probe has a better than 1-GHz bandwidth and can be used with the PerfectPulse signal generator for noninvasive circuit TDR and TDT testing.

PICOTEST CORP.,
Phoenix, AZ 85085, (877) 914-PICO, E-mail: info@picotest.com, *www.picotest.com*

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Low-Current MMIC Amplifier Keeps Gain Flat Through 16 GHz

Mini-Circuits' model EHA-163L+ is a low-current, wideband, monolithic amplifier with extremely flat gain from DC to 16 GHz. The amplifier provides tremendous lot-to-lot consistency and maintains flat gain with frequency, within ±0.75 dB of 14.9 dB to 12 GHz. The 50-Ω, Darlington-pair design operates on low current, typically 20 mA, and typical DC supply of +5 V dc. Input and output return loss is better than 10 dB and noise figure is typically 5.5 dB across the full frequency range. The RoHS-compliant is supplied in a 2 × 2 mm, 6-lead package and has an operating temperature range of -40 to +85°C.

MMIC Amp with Bypass Includes Fast Shutdown Time

Mini-Circuits' model TSS-183A+ is a surface-mount MMIC amplifier with high-speed shutdown feature for applications from 5 to 18 GHz. Ideal for radar, electronic-warfare (EW), and communications radios, the wideband 50-Ω amplifier achieves typical shutdown time of only 29 ns, protecting the amplifier from pulsed signals while maintaining constant supply voltage. It boasts 13.6-dB typical gain with ±0.9-dB gain flatness across the frequency range and as much as +17.9-dBm output power. The RoHS-compliant, unconditionally stable amplifier runs on a single +5-V dc supply and achieves typical isolation of 36 dB. It is fabricated with InGaAs pseudomorphic high-electron-mobility-transistor (pHEMT) semiconductor technology and supplied in a compact 3 × 3 mm MCLP surface-mount package.

High-Dynamic-Range Amplifier Boosts 30 MHz to 2 GHz

Mini-Circuits' model LHA-23LN+ is a wideband monolithic amplifier that combines high third-order intercept point (IP3) with low noise figure to achieve outstanding dynamic range from 30 MHz to 2 GHz. The monolithic E-PHEMT MMIC amplifier operates on low supply voltages of +3 to +5 V dc but manages a high IP3 of +36.9 dBm at 1 GHz with noise figure of 1.2 dB at 1 GHz. The RoHS-compliant amplifier achieves typical gain of 21.2 dB at 1 GHz. Output power at 1-dB compression is typically +18.8 dBm at 1 GHz for a +3-V dc supply and typically +23.8 dBm at 1 GHz for a +5-V dc supply. The amplifier is designed for operating temperatures from -40 to +105°C and is supplied in a 12-lead MCLP package measuring just 3 × 3 mm.

Flexible Cables Connect DC to 18 GHz

Mini-Circuits' model FL141-6SMNM+ flexible coaxial cable offers excellent electrical performance from DC to 18 GHz while providing tight bend radius of 10 mm. The 6-in.-long, 50-Ω cable assemblies are terminated with a male SMA connector and male Type N connector meeting MIL-STD-348 interface requirements. The flexible cables, which are ideal for communications systems and measurement applications, have low insertion loss of 0.26 dB at 18 GHz, with return loss of typically 32 dB at 6 GHz and 28 dB at 18 GHz. The power-handling capability is 140 W at 1 GHz, 57 W at 500 MHz, and 33 W at 18 GHz. These flexible cables are RoHS compliant and can be readily formed into tight shapes to replace custom-bent 0.141-in.-diameter semirigid cable sections.

90-deg. Power Splitter Channels 225 to 400 W

Mini-Circuits' model QCH-451 is a two-way, 90-deg. power splitter for applications from 225 to 400 MHz. It provides the outstanding amplitude and phase balance needed for both commercial and military systems, with typical amplitude unbalance of ±0.25 dB between channels and typical phase unbalance between channels of ±1.4 deg. The splitter can handle input power levels to 250 W with only 0.2-dB typical insertion loss across the full frequency range. The isolation between channels is typically 27 dB. Well suited for defense and commercial communications systems, the 90-deg. power splitter is designed for operating temperatures from -55 to +105°C. The compact power splitter measures just 1.26 × 0.5 × 0.078 in. with wrap-around terminations.

VCO Tunes from 335 to 365 MHz

Mini-Circuits' model ROS-365-119R+ is a miniature voltage-controlled oscillator (VCO) with tuning range of 335 to 365 MHz. It operates on tuning voltages of 0.5 to 5.0 V dc with 0.5 MHz typical pulling and 0.2 MHz/V typical pushing. The VCO draws 30 mA from a +5 V dc supply while providing +6.5 dBm typical output power. It features -21 dBc typical harmonic suppression with typical phase noise of -119 dBc/Hz offset 10 kHz from the carrier. The RoHS-compliant VCO is a good match for military and commercial communications systems and for radar systems. It is designed for operating temperatures of -55 to +85°C and fits within a compact housing measuring just 0.50 × 0.50 × 0.18 in.

GaAs MMIC Equalizers Help Level Amplitude to 6 GHz

THE EQY SERIES of absorptive gain equalizers provide tightly controlled attenuation slopes for achieving broadband, flat amplitude with frequency. Fabricated by means of a proven GaAs MMIC process with integrated passive devices (IPDs), the equalizers can be used to flatten a system's amplitude response by compensating for the gain slope of amplifiers, receivers, and transmitters in RF/microwave designs from dc through 6 GHz. The equalizers are available with nominal attenuation slopes of 1, 2, 3, 4, 5, 6, 8, and 10 dB, adding predictable attenuation with frequency. The equalizers are rated for input power levels to +31 dBm and operating temperatures from –40 to +85°C. They are packaged in tiny 2- × 2-mm, 8-lead MCLPTM housings.

MINI-CIRCUITS, P. O. Box 350166, Brooklyn, NY 11235-003; (718) 934-4500, *www.minicircuits.com*

System Simulator Tackles Advanced Modeling Challenges

THE LATEST VERSION of MapleSim 2018 system-level simulation software enables modeling of digital twins as well as many other complex system-level projects to reduce both development cost and time. The software also features improved connectivity with other modeling tools, for use across a wide range of industries and applications, especially in mechanical design for optimizing the motion of moving parts. A new one-dimensional (1D) Motion Generation App can create motion profiles according to defined velocity and acceleration limits for the design of motors and other moving parts. Links to more tools, such as the MapleSim Heat Transfer Library from CYBERNET, enable the study of heat-transfer effects when performing thermal-management analysis. The simulation software is available in English, French, and Japanese languages.

MAPLESOFT, 615 Kumpf Dr., Waterloo, Ontario N2V 1K8 Canada, *www.maplesoft.com*

Gooseneck Antennas Extend UHF to C Band

A GOOSENECK ANTENNA, which operates from 400 MHz to 6 GHz in a compact form factor with a flexible gooseneck base, can be used for UHF to C-band frequencies. The antenna features a dipole pattern with vertical polarization and utilizes a TNC connector. The gooseneck feature decouples the RF/microwave connector from the main antenna radiating element and allows the antenna to be adjusted to any position in the upper hemisphere above the connector. The gooseneck antennas are available for commercial cellular communications applications as well as military tactical radio applications.

PHARAD LLC, 1340 Charwood Rd., Hanover, MD 21076; (410) 590-3333, FAX: (410) 590-3555, *www.pharad.com*

Compact Calibration Kits Prepare VNAs for 26.5 GHz

PRECISION RF/MICROWAVE test equipment such as a vector network analyzer (VNA) requires calibration for accuracy. To address that issue, a new series of compact gold-plated, 4-in-1 short-open-load-through (SOLT) calibration kits were developed that feature low loss and excellent phase stability from dc through 26.5 GHz. The calibration kits, which are terminated with 3.5-mm connectors, include a handy lanyard and are well-suited for in-field test-and-measurement applications. They have worst-case phase deviation of ±2 deg. and minimum return loss of 30 dB at an impedance of 50 Ω from dc through 26.5 GHz. They also have off-the-shelf availability for same-day shipping.

FAIRVIEW MICROWAVE INC., 301 Leora Ln., Ste. 100, Lewisville, TX 75056; (800) 715-4396 / (972) 649-6678, FAX: (972) 649-6689, E-mail: sales@fairviewmicrowave.com, *www.fairviewmicrowave.com*

Phase-Coherent Signal Generator Reaches 20 GHz with Many Channels

MODEL 855 IS A phase-coherent multi-channel signal generator that can be specified for use from 10 MHz to frequencies as high as 20 GHz. Versions are available with high-end frequencies of 6.2, 12.5, and 20.0 GHz, and 2, 4, or 8 channels, to meet a wide range of measurement applications. The phase noise is –131 dBc/Hz offset 1 kHz from a 300-MHz carrier, –115 dBc/Hz offset 1 kHz from a 4-GHz carrier, and –100 dBc/Hz offset 1 kHz from a 20-GHz carrier. Signal output-power levels can be set from –20 to +20 dBm across the full frequency range (to 20 GHz), with 0.1-deg. phase resolution and 0.02-ms switching speed.

The signal generator bases excellent phase and amplitude stability on an internal oven-controlled crystal-oscillator (OCXO) reference source, but can also operate with external clock oscillators at 10, 100, or 1000 MHz. The generator is supplied with as many as four independent channels in a standard 1U 19-in.-wide rack-mount configuration, and as many as eight independent channels in a standard 3U 19-in.-wide rack-mount configuration. It can be controlled by means of USB, LAN, or GPIB, and works with many software programs, including MATLAB, LabVIEW, and C++, for automatic testing.

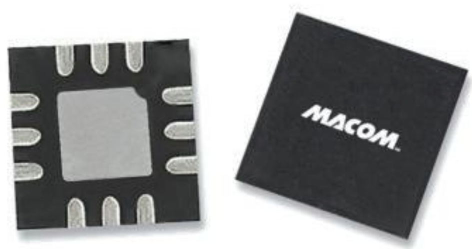
BERKELEY NUCLEONICS CORP., 2955 Kermer Blvd., San Rafael, CA 94901; (800) 234-7858,E-mail: info@berkeleynucleonics.com, *www.berkeleynucleonics.com*

High-Definition Scopes Scan to 8 GHz

THE WAVEPRO HD high-definition oscilloscopes leverage HD4096 technology with 12-b analog-to-digital converters (ADCs) for capturing and displaying high-speed waveforms from dc to 8 GHz in various models. WavePro oscilloscope models are available with vertical analog channels of 2.5, 4.0, 6.0, and 8.0 GHz, and respective risetimes of 117, 73, 50, and 40.5 ps. All of the oscilloscopes feature sampling rates to 20 Gsamples/s, as much as 5-Gpoint signal acquisition memory, and 1900- × 1080-pixel capacitive touchscreens. Sensitivity levels are fully variable from 1 to 10 V/div. The channel-to-channel isolation is as high as 70 dB to 200 MHz, 40 dB to 2.5 GHz, and 30 dB to 6 and 8 GHz. A powerful, deep toolbox of measurement functions is included with each scope.

TELEDYNE LECROY, 700 Chestnut Ridge Rd., Chestnut Ridge, NY 10977; (845) 425-2000, *www.teledynelecroy.com*

Double-Balanced Mixers Provide Conversion to 46 GHz



THE MAMX SERIES of RF/microwave mixers are designed for broadband applications as high as 46 GHz. Introduced at the recent 2018 IMS in Philadelphia, the mixers are well-suited for frequency conversion in microwave radios and radar systems. They come in chip and packaged forms. Model MAMX-011036 is supplied in a 3- × 3-mm, 12-lead 12LAQFN housing and has an RF/LO range of 8 to 43 GHz with an IF bandwidth of 0 to 10 GHz. It works with +15-dBm LO power and has 8.5-dB typical conversion loss, but achieves a +20-dBm input third-order intercept point (IP3). The LO-to-RF isolation is 40 dB, LO-to-IF isolation is 35 dB, and RF-to-IF isolation is 25 dB. Model MAMX-011036-DIE is supplied in die form for RF/LO use from 8 to 43 GHz with 8.0-dB conversion loss. It's designed for +15-dBm LO power and has +20-dBm input IP3. The chip mixer maintains an IF bandwidth of 0 to 10 GHz with typical LO-to-RF isolation of 40 dB, typical LO-to-IF isolation of 35 dB, and typical RF-to-IF isolation of 25 dB. The mixer in die form measures 1.20 × 0.97 × 0.10 mm.

MACOM TECHNOLOGY SOLUTIONS INC., 100 Chelmsford St., Lowell, MA 01851; (800) 366-2266, *www.macom.com*

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