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http://www.pmi-rf.com/Products/Switches/standardmodels.htm

Model: P2T-1G1R1G-25-R-SFF-100W

Frequency	1.0 to 1.1 GHz
Isolation	25 dB Min - Measured 40.09 dB
VSWR	1.5:1 Typ
Insertion Loss	0.8 dB Max - Measured 0.49 dB
RF Input Power	100 Watts CW Max / 5 kW peak – Tested to 100 W CW
Switching Speed	100 ns Max – Measured 61.6 ns
Temperature	-45 ºC to +85 ºC Operating

Package Size:
4.22” x 2.98” x 0.70”
Connectors: TNC (F)
DC Voltage:
+5 VDC @ 135 mA
-50 VDC @ 17 mA

Model: PSM-1G1R1G-TRSW-2500W

Frequency	1.0 to 1.1 GHz
Isolation	25 dB Min (J2-J3) - Measured 38 dB 60 dB Min (J2-J4) - Measured 65 dB
VSWR	1.4:1 Typ
Insertion Loss	1.0 dB Max (Tx Mode) - Measured 0.67 dB 0.8 dB Max (Rx Mode) - Measured 0.54 dB
RF Input Power	2.5 KW Peak (J1 Only)
Switching Speed	385 ns Typ - Measured 300 ns @ 2 kHz Switching Rate Max
Temperature	-45 ºC to +85 ºC Operating

Package Size:
7.750” x 3.000” x 0.575”
Connectors: SMA (F)
DC Voltage:
+5 VDC @ 360 mA
+50 VDC @ 30 mA

Model: P2T-1G18G-10-R-528-SFF-HIP10W

Frequency	0.1 to 18.0 GHz
Isolation	25 dB Min - Measured 25.73 dB
VSWR	2.0:1 Max - Measured 1.76:1
Insertion Loss	3.5 dB Max - Measured 2.66 dB
RF Input Power	10 Watts CW Max - Tested at 10 W CW
Switching Speed	200 ns Max - Measured 60 ns
Temperature	-54 ºC to +100 ºC

Package Size:
1.2” x 1.0” x 0.5”
Connectors: SMA (F)
DC Voltage:
+5 VDC @ 2.19 mA
-28 VDC @ 2.25 mA

Model: PEC-9R510R7-100W-SFF-SPDT

Frequency	9.5 to 10.7 GHz
Isolation	40 dB Min - Measured 44.49 dB
VSWR	2.0:1 Max - Measured 1.42:1
Insertion Loss	1.5 dB Max - Measured 1.34 dB
RF Input Power	120 Watts CW
Switching Speed	400 ns Max - Measured <300 ns
Temperature	-55 ºC to +85 ºC Operating

Package Size:
2.12” x 1.18” x 0.51”
Connectors: SMA (F)
DC Voltage:
+5 VDC @ 135 mA
-28 VDC @ 5 mA

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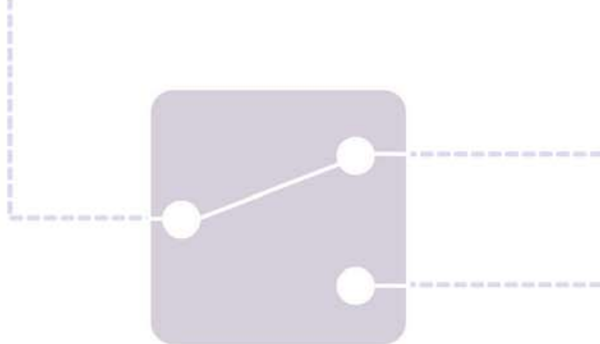

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CEL Part Numbers	Switch Type	MAX Freq. (GHz)	Insertion Loss (dB)		Isolation (dB)		P0.1dB (dBm)		Package Type
			2.5 GHz	6.0 GHz	2.5 GHz	6.0 GHz	2.5 GHz	6.0 GHz	
CG2179M2	SPDT	3.0	0.45	N/A	26	N/A	+30	N/A	(1.25 x 2.0 x 0.9)
CG2214M6	SPDT	3.0	0.35	N/A	25	N/A	+30	N/A	(1.1 x 1.5 x 0.55)
CG2163X3	SPDT	6.0	0.40	0.50	40	31	+29	+28	(1.5 x 1.5 x 0.37)
CG2185X2	SPDT	6.0	0.35	0.40	28	26	+29	+29	(1.0 x 1.0 x 0.37)
CG2176X3	Absorptive SPDT	6.0	0.45	0.55	30	22	+35	+37	(1.5 x 1.5 x 0.37)
CG2415M6	SPDT	6.0	0.35	0.45	32	26	+31	+31	(1.1 x 1.5 x 0.55)
CG2430X1	SP3T	6.0	0.50	0.60	28	25	+28	+28	(1.5 x 1.5 x 0.37)

CEL WWW.CEL.COM/SWITCHES

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This compact power divider passes signals from 1.0 to 4.8 GHz and from 6.2 to 9.0 GHz, in addition to including a rejection band to stop WLAN interference from 5.0 to 5.8 GHz.

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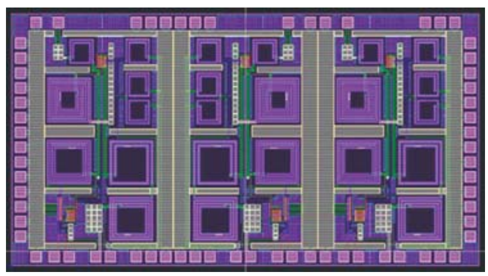

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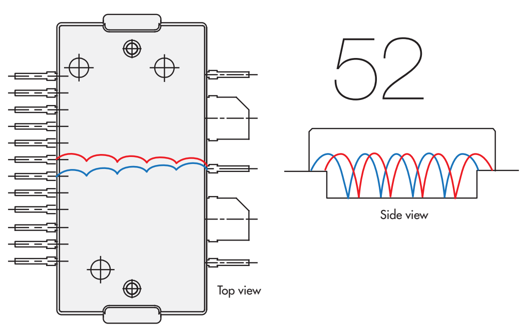

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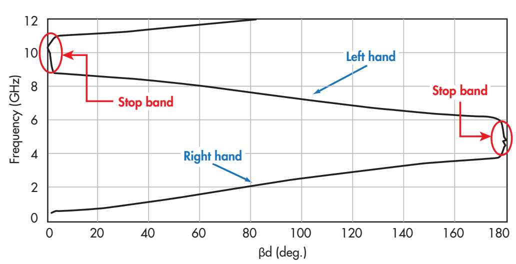

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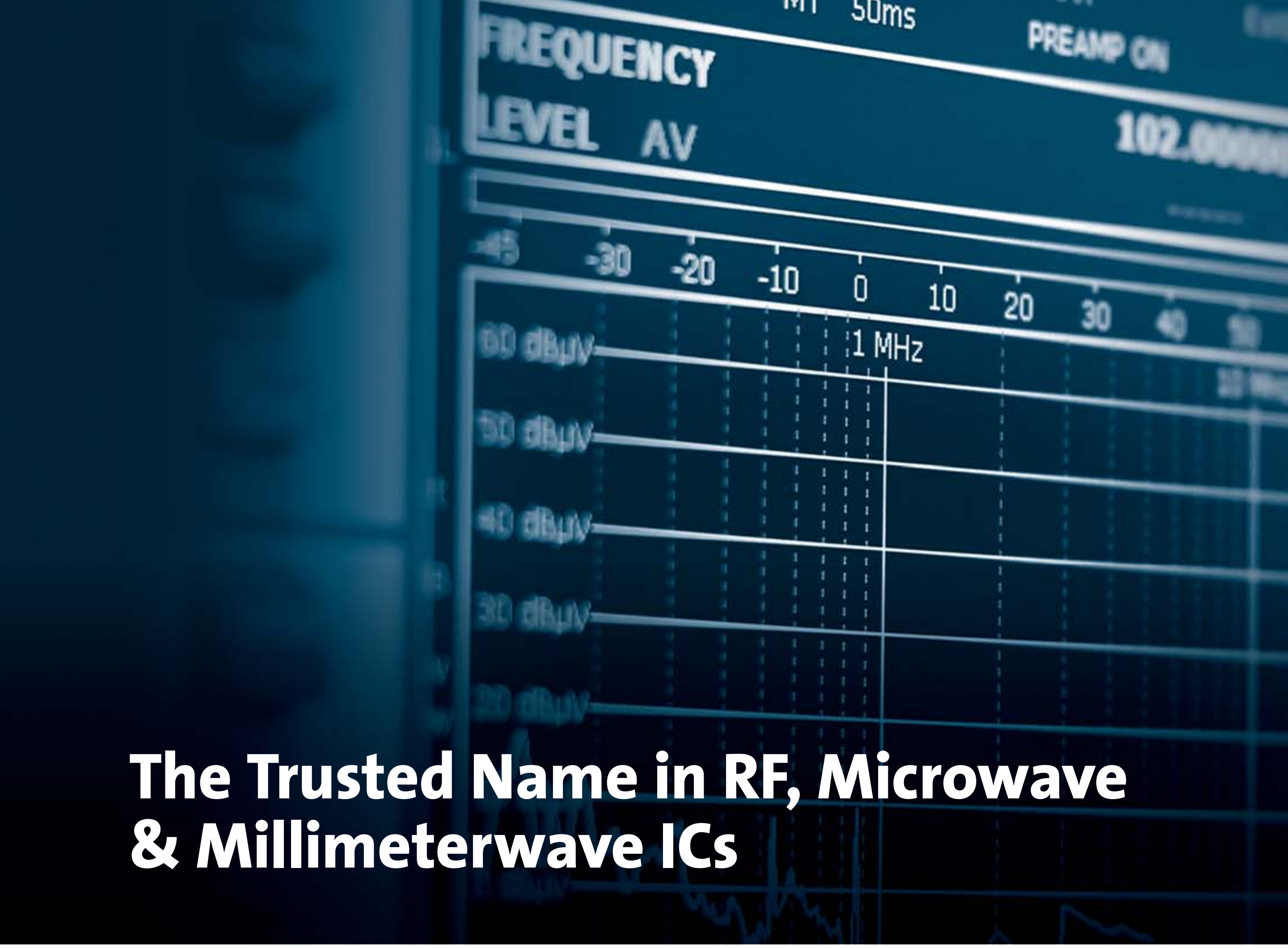

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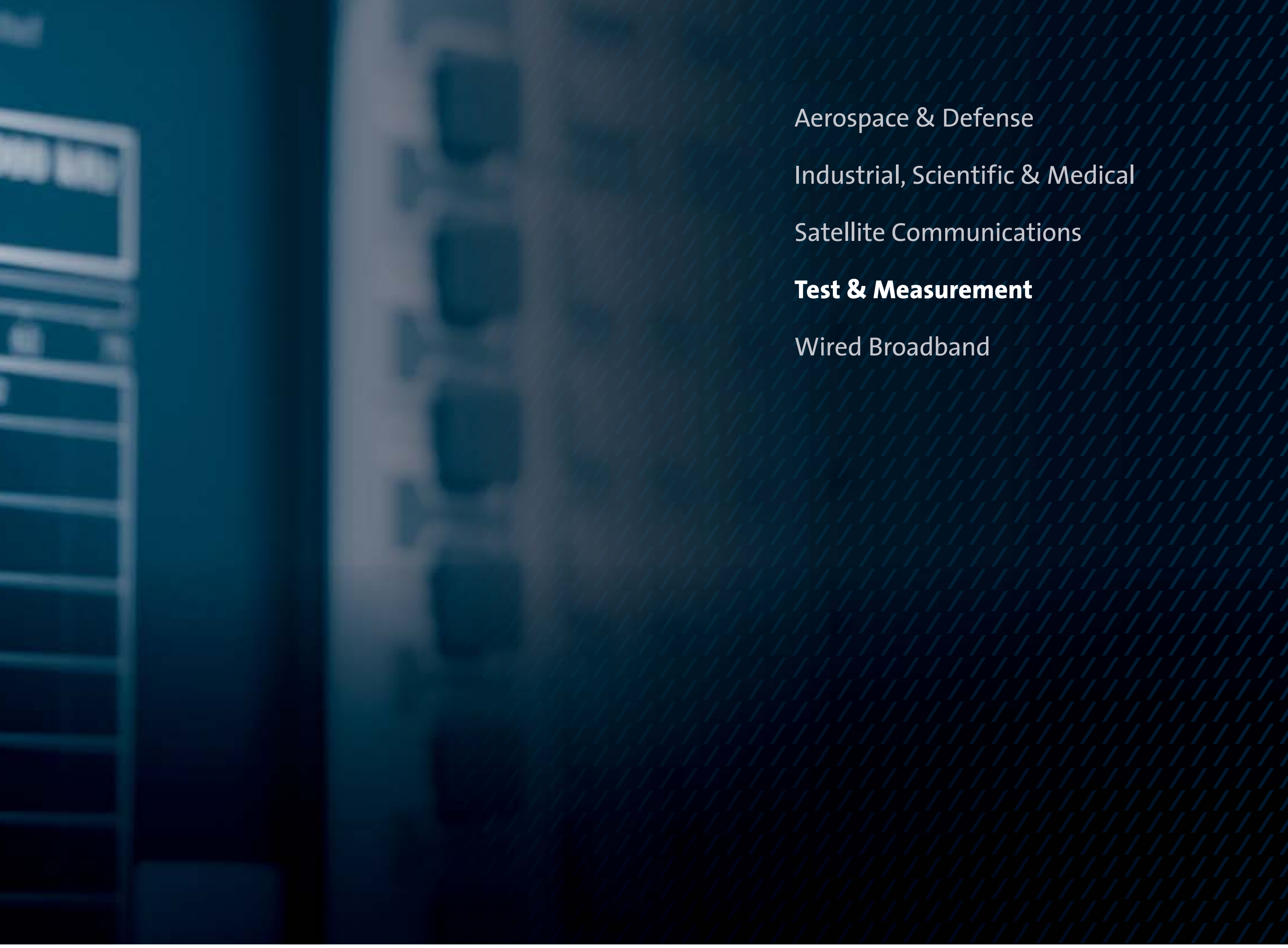
Featured MACOM MMIC Devices

Application	Function	Part Number
Test & Measurement	Wideband Power Amplifier	MAAP-011247, DC - 22 GHz
	Wideband Low Noise Amplifier	MAAL-011141, DC - 26.5 GHz
	Wideband DBL BAL Mixer	MAMX-011036, 8 - 43 GHz
SATCOM	Ka-Band Power Amplifier	MAAP-011289, 28 - 30.5 GHz
	Doubler Power Amplifier	MAFC-011009, 28 - 30 GHz
	L-Band Power Amplifier Module	MAAP-011060, 1616 - 1627 MHz
Aerospace & Defense	Octave Band VCO	MAOC-415000, 10 - 20 GHz
	Power Amplifier	MAAP-011232, 0.1 - 3 GHz
Industrial, Scientific & Medical	Low Noise Amplifier	MAAL-011129, 18 - 32 GHz
	Gain Block	MAAM-011206, DC - 15 GHz
Wired Broadband	Variable Gain Amplifier	MAAM-011194, 45 - 1218 MHz
	Gain Block	MAAM-011220, 45 - 1218 MHz
	Very Low Noise Amplifier	MAAL-011136, 45 - 1218 MHz



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- mmW Switches
- Wideband Detectors
- Broadband 75 ohm Amplifiers

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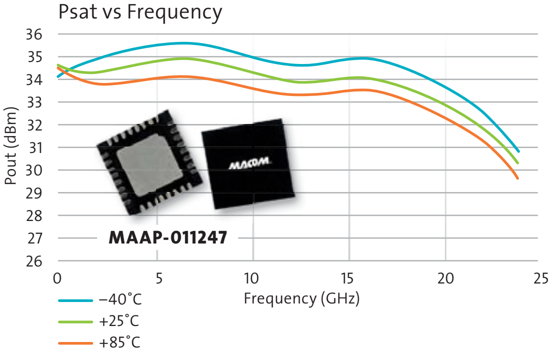

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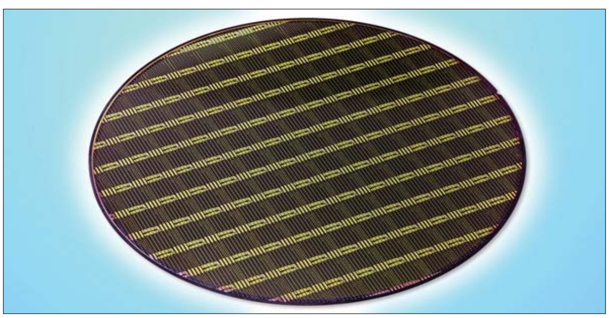
2016 SALARY & CAREER REPORT: A POSITIVE (IF NOT PERFECT) OUTLOOK

http://mwrf.com/learning-resources/2016-microwaves-rf-annual-salary-career-report-all-quiet-compensation-front

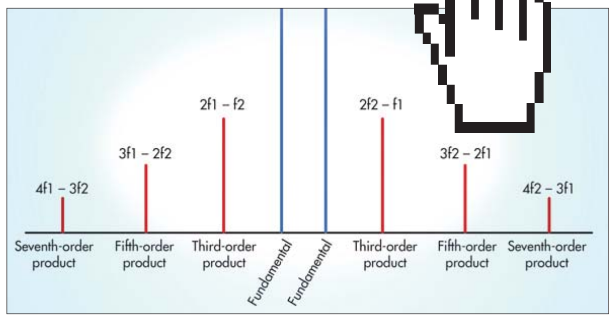
What's some of the good news to come out of this year's *Microwaves & RF* Annual Salary & Career Report? According to respondents, the RF/microwave industry is continuing to provide stable salaries along with high job satisfaction. But for all of that, work environment concerns still persist.



WHAT'S THE DIFFERENCE BETWEEN MIMO AND MMICS?

http://mwrf.com/analog-semiconductors/what-s-difference-between-mimo-and-mmics

Modern wireless systems have long depended on monolithic microwave integrated circuits (MMICs) and are increasingly relying on the use of multiple-input, multiple-output (MIMO) antenna techniques. As much as these abbreviations seem similar, what exactly is each technology and what roles do each play in a wireless system?



MATERIALS MAKE THE DIFFERENCE IN LOW-PIM PCB ANTENNAS

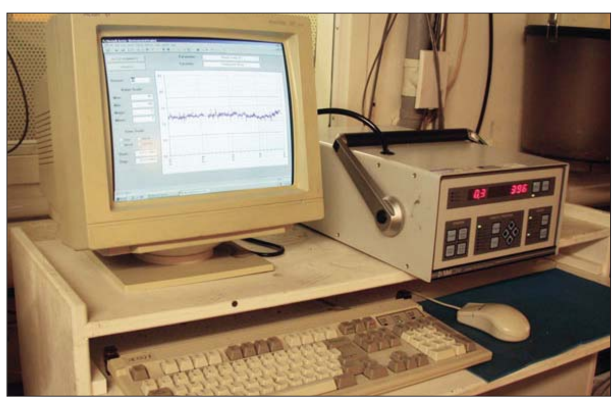
http://mwrf.com/materials/materials-make-difference-low-pim-pcb-antennas

Antennas are the beginning and end components of many communications systems, and the performance of modern wireless communications networks depends on these antennas achieving low passive-intermodulation (PIM) levels. While PIM is not caused by circuit materials, these materials can help to lower it in PIM-sensitive applications.

DIFFERENTIATING BAW AND SAW TECHNOLOGIES

http://mwrf.com/components/differentiating-baw-and-saw-technologies

Acoustic waves are part of the operating mechanisms of both surface-acoustic-wave (SAW) and bulk-acoustic-wave (BAW) components, although the two acoustic component types and technologies have essential differences. Still, both technologies provide effective circuits within their frequency ranges, and in small sizes that make them attractive for a wide number of applications in commercial, industrial, and military systems. (Photo Courtesy of Phonon Corp.)



Editorial

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Will Your Design and Test Flow Soon Be Obsolete?

Recently, Todd Cutler from Keysight Technologies delivered an interesting keynote speech at EDI CON 2016 titled, "High-Frequency, High-Speed Design Revolution Ahead: Why Your Design and Test Flow Will Soon Be Obsolete." Cutler, who is vice president and general manager of design and test software at Keysight, was clearly making a bold statement by declaring this, and he does have solid reasons for believing this. With that being said, engineers should at least be prompted to think about whether or not their current design flow will soon be outdated.

According to Cutler, today's design and test tools are vastly superior to those used in the past. However, the same basic workflow is still followed today. That workflow is basically performed in this order: simulate, prototype, manufacture, and optimize.

Will the same workflow be adequate several years from now? Cutler doesn't think so. He points out that channel complexity is exploding, specifically mentioning technology like massive multiple input, multiple output (MIMO). And data volume is exploding, with petabytes of data moving between data centers, according to Cutler. He states that designing and testing base stations for the Internet of Things (IoT) will involve 50,000 (50,000!) simultaneous channels. That number alone may lead one to believe that future design and test approaches must change. At least that's what Cutler believes, as he noted in his presentation, "The old way of working will not work."

In the future, Cutler believes that "complexity will drive workflow coherency." His future design flow incorporates a blend of simulation and measurement. In other words, he believes that full systems will need to be prototyped immediately after simulations are first executed. After this initial prototyping, more simulations will be performed based on the measured prototype results to refine system-level designs. Simulating and testing are performed with identical measurements and specifications. Cutler thinks this approach of early prototyping represents future design flows.

As the IoT moves along and with 5G on its way, it will be interesting to see if design and test approaches drastically change. Several years from now, will design and test flows look the same as they do now? Cutler and those who agree with him don't believe so. Will your design and test flow soon be obsolete? Maybe that's a question you need to ask yourself. mw

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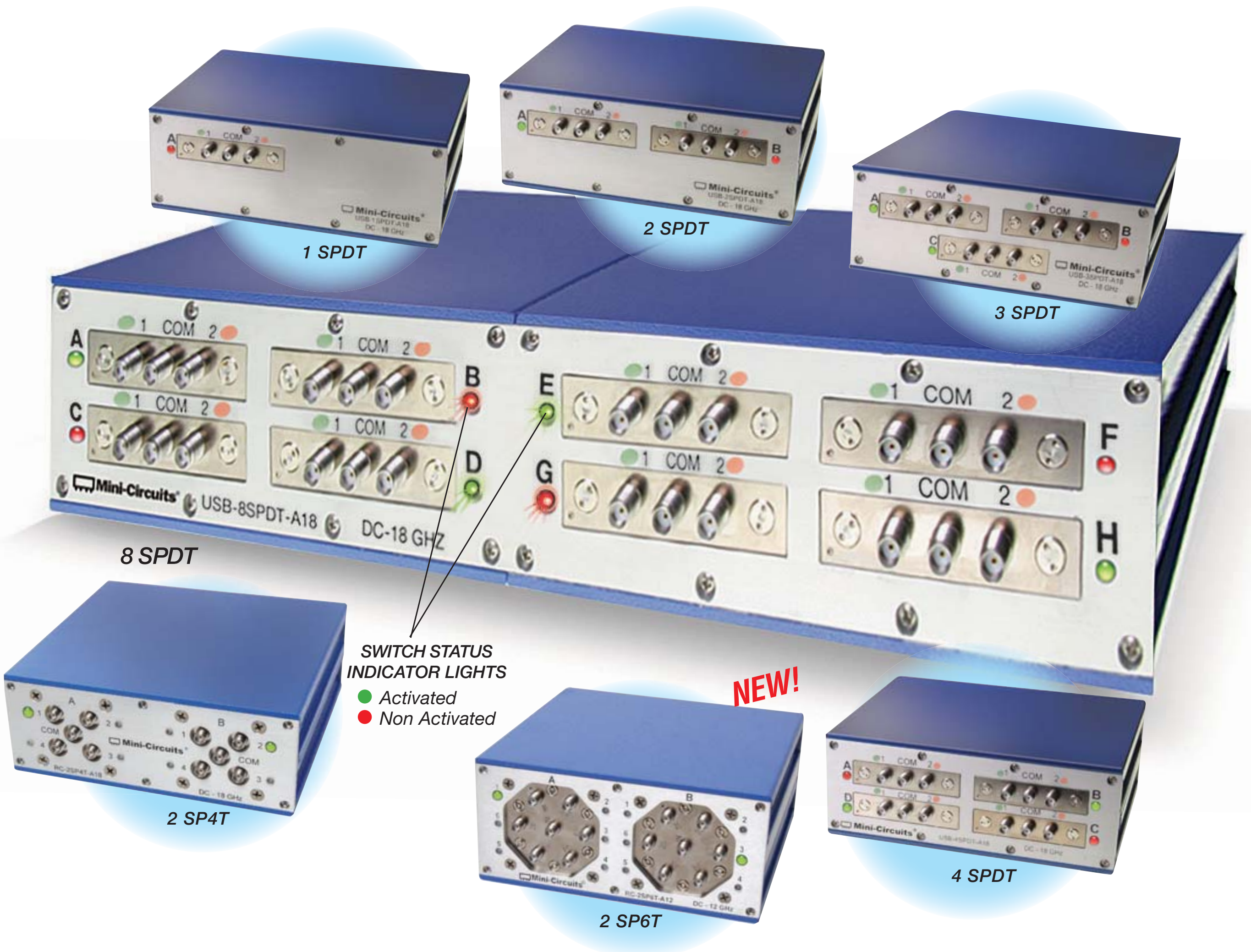
DC to 18 GHz



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NEW!	PWR-6RMS-RC	True RMS	50 to 6000	-35 to +20	USB & Ethernet	1595.00
	PWR-4RMS	True RMS	50 to 4000	-35 to +20	USB	1169.00
	PWR-2.5GHS-75 (75Ω)	CW	0.1 to 2500	-30 to +20	USB	795.00
	PWR-4GHS	CW	0.009 to 4000	-30 to +20	USB	795.00
	PWR-6GHS	CW	1 to 6000	-30 to +20	USB	695.00
	PWR-8GHS	CW	1 to 8000	-30 to +20	USB	869.00
	PWR-8GHS-RC	CW	1 to 8000	-30 to +20	USB & Ethernet	969.00
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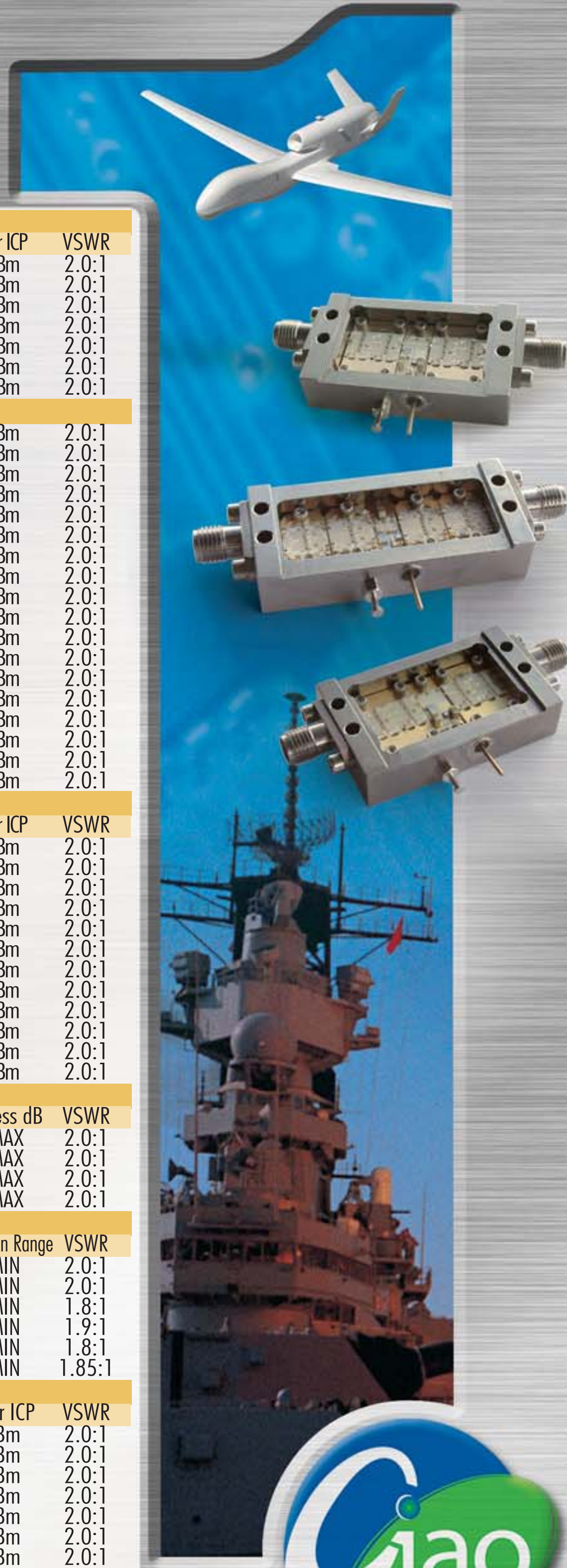

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Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+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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HOW LONG DOES A PORTABLE RUN?

The article in your October 2016 issue on portable spectrum analyzers, “Portable Testers Add Real-Time Spectrum Analysis to 50 GHz,” provided an interesting look at one company’s line of portable in-field analyzers, although it could have done a lot more. While the table provided a useful quick look at all of the spectrum analyzers in the product line, again, it is only one company’s (Keysight Technologies) test instruments and does not provide a comprehensive look at some of the other portable spectrum analyzers in the industry.

Should you decide to write a more complete survey of portable spectrum analyzers in the future, can I suggest that you include some of the information that was missing in this first attempt? For example, this article spent a great deal of space on sweep times and minimum pulse widths and dynamic range, but never mentioned one of the most important times of all for a portable instrument: How long does it last on a single charge of the battery?

For in-field measurements, and one of the main reasons for purchasing a portable test instrument, there may not be clear access to a power source and the instrument may depend solely on the built-in rechargeable battery. Your review mentions that these analyzers can run for as long as four hours on a single charge, but it doesn’t provide any details on the operating conditions or what types of measurements can be performed to make it last that long on that charge. Your review also fails to report on the amount of time required to recharge the battery.

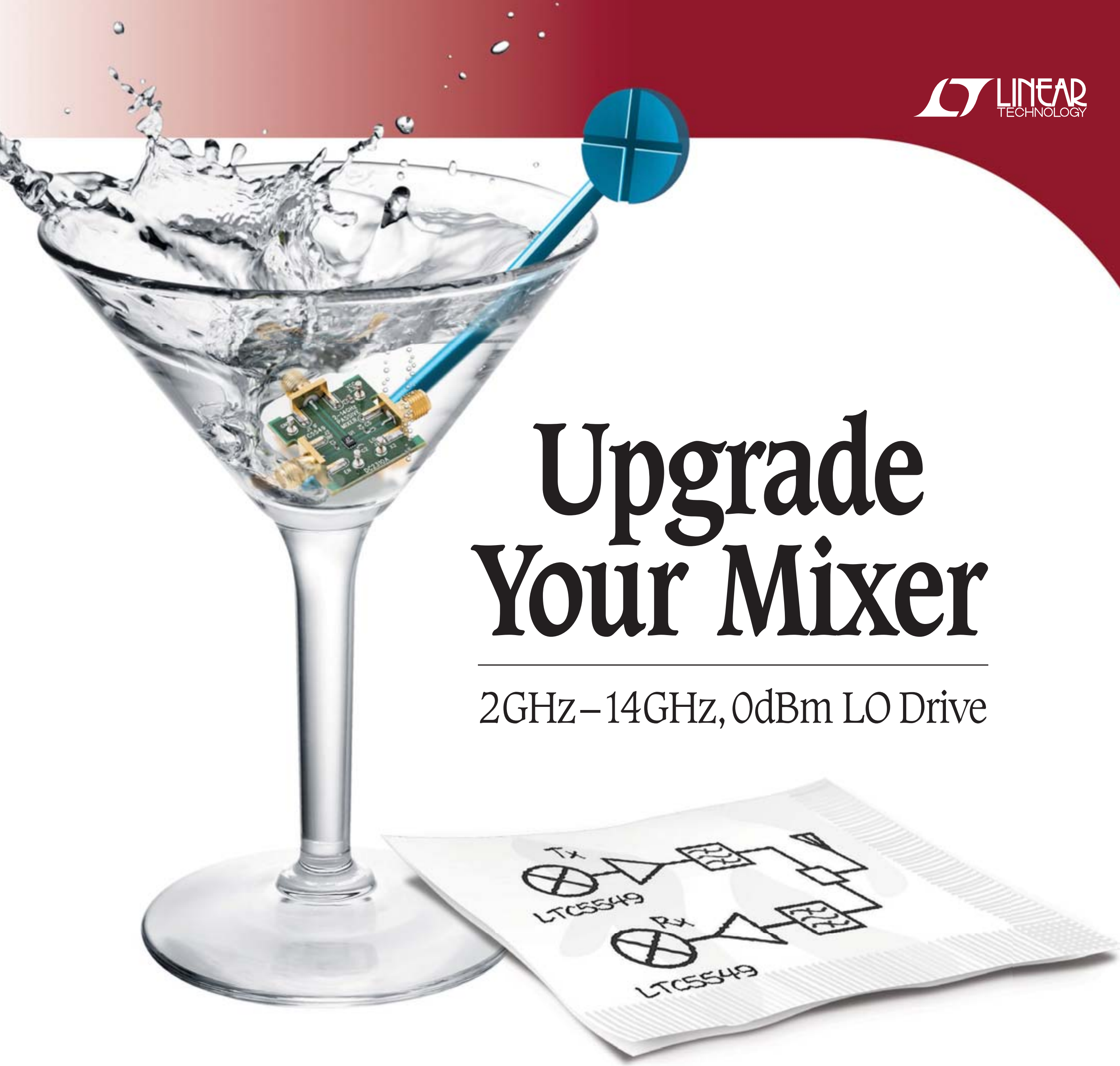
What could be useful for your readers is a comprehensive report, or series of reports, on all portable RF/microwave test instruments from all manufacturers. And don’t forget to note how long those batteries last!

MARK BISSETTE

EDITOR’S NOTE

My thanks for your thoughts and for your excellent suggestions. The report you saw in the October *Microwaves & RF* (p. 92) issue was meant as a Product Feature review of a single company’s new line of portable spectrum analyzers, focusing on only that product line rather than instruments from other suppliers. Please watch these pages in the coming year (2017), and we hope to be able to fulfill your wishes.

JACK BROWNE
TECHNICAL CONTRIBUTOR



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- Upconversion or Downconversion
- –30dBm LO Leakage
- Tiny 3mm x 2mm Package

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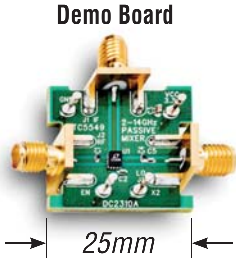

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News

NETWORK ANALYZER
to Measure Terahertz Signals

Now that wireless companies are testing high-frequency bands for things like video and music streaming, it's easy to find network analyzers that measure millimeter waves. But if you need to measure terahertz frequencies, you might have to search a little harder.

Keysight Technologies is trying to change that with the new version of a network analyzer it revealed last month. The test equipment maker said that it had developed a 1.5 THz network analyzer for the Chalmers University of Technology in Sweden, where researchers are studying circuits that can handle high-frequency wireless signals.

The new device might give an image boost to Keysight, which traces its roots to Hewlett-Packard's electronic test division, and which has started to design test equipment for measuring frequencies between 100 and 1000 GHz. Engineers have had significant trouble making wireless technology to transmit and receive these high frequency bands, and making accurate measurements has proved just as difficult.

Doctors are looking into THz scanners to analyze breast tumors and other cancers. *(Image courtesy of Indi Samarajiva, Creative Commons)*

The test equipment is built around Keysight's PNA-X network analyzer, which alone measures frequencies between 10 megahertz and 67 gigahertz. The company upgraded the equipment with an external module developed by Virginia Diodes, a small company based in Virginia that makes modules that bolt onto test equipment to extend their range into the millimeter wave and THz spectrum.

The researchers at Chalmers are working on THz components, including a new transistor design that can be mass-produced cheaply. It is also trying to fuse these circuits with passive components like filters and antennas into a single stack of silicon.

The major obstacle to using these frequency bands is the lack of technology capable of generating signals powerful enough to transmit data. The THz components that are available are typically too expensive, bulky, and power-hungry for commercial use. The payoff, though, could be gigantic: above 100 GHz, there are several hundred gigahertz of bandwidth for applications ranging from communications to wireless imaging.

Doctors are looking into THz scanners to analyze breast tumors and other cancers. Security firms have proposed using similar technology to look inside bags for concealed explosives—and determine what they are made of. It can also be used to find hidden defects in materials like ceramic, faults in semiconductors wafers, and hidden layers of paint underneath paintings.

Reaching the frequency is only part of the challenge. Because it is difficult to generate strong signals, it is also challenging to cancel out noisy interference.

Keysight is not the only test equipment maker tackling accuracy problems. Anritsu and Rohde & Schwarz are both working to extend the frequency range of their test equipment, using parts from companies like Virginia Diodes and Oleson Microwave Labs. ■

QUANTENNA DEVELOPS WI-FI CHIPS Based on Early Draft of 802.11ax

QUANTENNA HAS EARNED a reputation for being first to release wireless chips based on new generations of Wi-Fi. The company, which makes Wi-Fi chips for routers and set-top boxes, was the first to announce hardware based on the 802.11ac version of the radio technology in 2011.

Last month, the chipmaker said that it had extended that streak. It revealed details about the first chip to comply with an early version of the 802.11ax standard, which aims to wring better capacity and faster download speed out of Wi-Fi.

The chip, QSR10G-AX, is the first known chip based on the new standard, which is scheduled to be released in 2019. Quantenna unveiled the chip, which is designed specifically for access points, at last month's World Broadband Forum in London.

It is built on the same architecture that Quantenna created for the latest version of the 802.11ac standard, which is capable of downloading 10 gigabits of data per second. The new Quantenna chip is a drop-in replacement for older chips based on the architecture, called QSR10G.

The Wi-Fi Alliance is planning 802.11ax as a significant upgrade to the 802.11ac standard. It will coordinate multiple antennas to send multiple streams of data to devices, with each stream split again with orthogonal frequency division multiple access, or OFDMA, a variant of the technology used in cellular networks. The result is a bigger pipeline for devices to transmit data.

That contrasts with earlier technologies, which created multiple streams but only assigned one to each device. The new standard will be more efficient and provide download speeds over 10 gigabits per second. It aims to provide better coverage in places filled to the brim with mobile devices and connected sensors, like apartment buildings and offices.

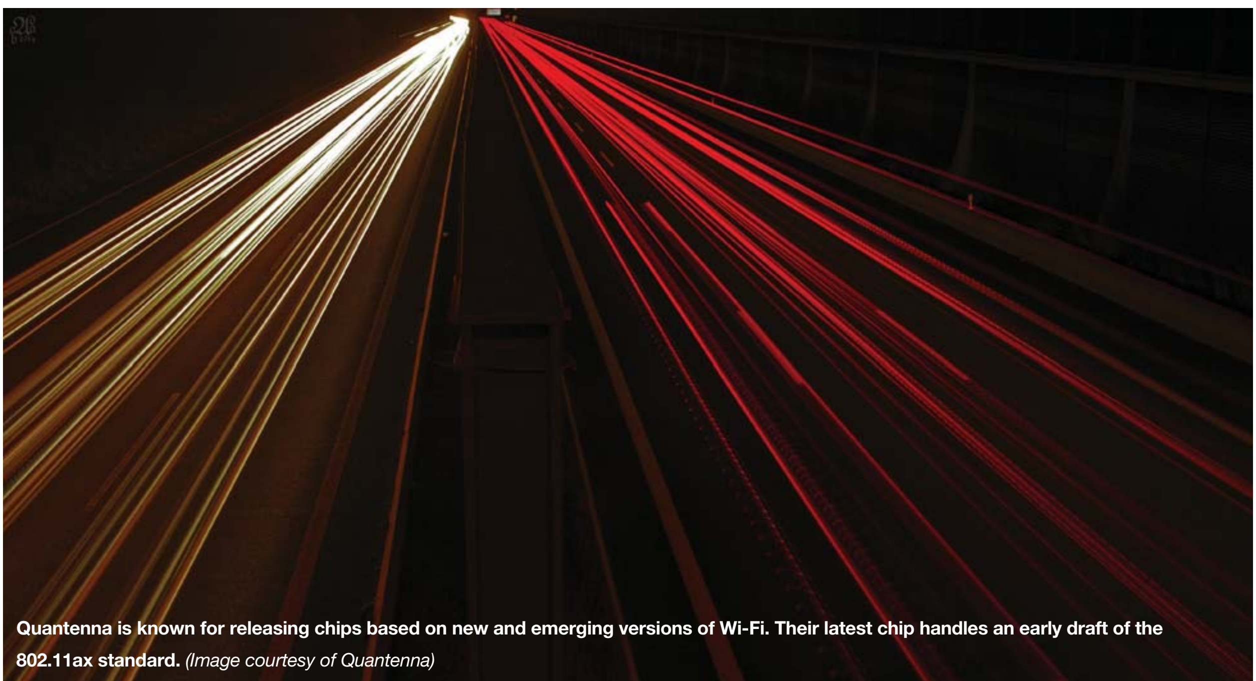
In the view of industry analysts, the 802.11ax standard will become one of the major evolutionary stages of Wi-Fi, while others like HaLow will splinter into specialized applications. More than half the Wi-Fi chips sold in 2021 will employ 802.11ax, according to Andrew Zignani, an industry analyst at ABI Research, a technology research firm. He also estimates that more than 20 billion Wi-Fi chips will ship between 2016 and 2021.

It will also push Wi-Fi further into the 5 GHz spectrum, which holds more room for wireless traffic than the 2.4 GHz band used by other standards. The QSR10G-AX chip is capable of creating 12 streams, with eight in the 5 GHz band.

Founded in 2006, Quantenna makes Wi-Fi chips for wireless routers and set-top boxes. The company says that it has sold more than 60 million chips to telecommunications companies like AT&T and Telefonica. But it has also become known for releasing chips for embryonic Wi-Fi standards like 802.11ax.

The company released the first 802.11ac chip for consumer electronics nearly two months before Broadcom, the biggest maker of Wi-Fi chips for mobile devices and routers, in late 2011. Quantenna has also jumped ahead in chips based on new versions, or Waves, of the larger 802.11ac standard.

That quickness has encouraged investors to pour money into the Sunnyvale, Calif., company. It has raised around $160 million in



Quantenna is known for releasing chips based on new and emerging versions of Wi-Fi. Their latest chip handles an early draft of the 802.11ax standard. *(Image courtesy of Quantenna)* funding over the last decade from Sequoia Capital, DAG Ventures, Venrock, among others.

Quantenna's sharpening focus on new standards could give it more bargaining power with investors now that it has gone public. The company launched its initial public offering on the Nasdaq stock exchange, with an eye toward mustering over $100 million. Its stock ticker is QTNA.

It is a rare I.P.O. for the semiconductor industry. For chipmakers, venture capital funding has dried up over the last decade as the cost and time involved with making new chips has increased sharply.

In recent years, chipmakers have resorted to buying smaller and scrappier competitors in an attempt to keep growing and building more advanced chips. Earlier this year, Avago Technologies closed the bombshell $37 billion deal for Broadcom, one of Quantenna's biggest competitors.

Quantenna plans to begin sampling the QSR10G-AX chip in early 2017. It did not say when it would enter production. ■

POWER AMPLIFIER Startup Sells to Nokia

FOR YEARS, WIRELESS CHIPMAKERS have stayed in business by making circuits smaller and less likely to generate crippling heat. But power amplifiers, which turn electricity into radio signals, have always resisted big improvements.

That could explain the growing number of startups trying to make power amplifiers not only more efficient but easier to plug into existing circuits. And the wireless industry has taken notice.

Nokia said last week that it was buying Eta Devices, a startup based in Massachusetts that has created a new design for power amplifiers, one that conserves more energy than it wastes. The company claims that its technology cuts the power consumption of cell stations in half and doubles the battery life of smartphones.

The chipmaker, which was founded by electrical engineers from the Massachusetts Institute of Technology, has developed a new way of managing the huge amount of power wasted by smartphones when streaming video or downloading apps – and cell stations when transferring large files or connecting to thousands of devices.

Here, a Nokia cell station. *(Image courtesy of Nokia)*

Nokia, which builds the radio equipment used inside cell stations, did not reveal the terms of the deal.

The acquisition follows Nokia's strategy to lower the power consumption of its radio equipment, which the company is increasingly using in small cells instead of traditional radio towers. Last year, the company introduced power management software and new antennas that it said could reduce power consumption in cell stations by %70.

Eta Devices says that its power amplifiers are efficient enough to eliminate the need for backup power and bulky air conditioners, allowing for smaller cell station cabinets. The company says that its power management technology can be linked to other power amplifiers to improve efficiency.

Eta Devices was founded by two electrical engineering professors, Joel Dawson and David Perrault, in 2010. After two years of laying out blueprints for the new amplifiers, they received $6 million in funding from Ray Stata, one of the engineers that founded Analog Devices. Eta Devices now employs 20 people.

Dawson and Perrault, who enlisted a former Ericsson engineer to help with the power amplifier's design, describe their technology as an electronic gearbox. It sifts through different voltages sent across the chip's transistors and chooses one that minimizes power consumption. The company calls the process asymmetric multilevel outphasing.

Before it revealed the new power amplifiers in 2012, the company planned to sell its products in developing countries, where cell stations were often powered by diesel generators and more efficient parts could save fuel. Nokia has also signaled its willingness to install equipment in rural areas, partnering with Facebook's Telecom Infra Project to create new radio hardware that connects isolated communities to the internet.

Lowering power consumption in cell stations could also help cut costs for wireless carriers. That could be an important selling point for equipment makers like Nokia, which are competing for tighter profits as spending on fourth-generation wireless technology slows. Nokia's competitors are feeling the strain: last week, Ericsson said that it was cutting 3,000 employees in its home country of Sweden. ■

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QUALCOMM TO SAMPLE 5G Modem Chip in 2017

THE FIRST SPECIMENS of hardware based on 5G technology are almost here. Samsung Electronics says that it has built miniaturized antennas based on its understanding of the technology, while Mediatek has around 100 engineers working on 5G versions of its power-sipping silicon. But most chipmakers have stopped short of actual products.

That changed when Qualcomm announced its first chip for connecting smartphones, routers, sensors, and other gadgets to 5G networks. It went forward with announcing the modem in spite of the fact that an industry standard is still roughly four years away.

The chipmaker said that the Snapdragon X50 modem will deliver download speeds up to 5 gigabits per second, making it around 20 times faster than the latest fourth-generation technology. That speed is necessary, the company said, to create far more versatile networks.

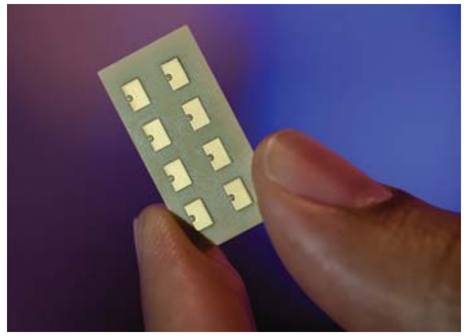
The San Diego-based company said that samples will be available in the second half of 2017. The first products using the modem will appear in 2018, it said.

The details of the Qualcomm chip include several features that are almost certain to be added to a 5G standard. The modem will operate over millimeter wave spectrum in the 28 GHz band, coordinate multiple antennas to lower latency and hasten downloads, and bend antenna beams to improve reliability.

But the final definition of the standard is still not finished. Qualcomm might eventually have to redesign its modems to conform to new versions of the standard. Most wireless carriers don't plan to offer 5G networks before 2020.

But not everyone wants to wait another four years for the final standard. Verizon plans to launch preliminary 5G networks in 2017, and wireless carriers in South Korea are aiming to provide new services during the Winter Olympics in 2018.

5G is expected to provide massive improvements over existing technology. People using smartphones on 5G net-



A prototype of the X50 modem's antenna array. The chip will coordinate multiple antennas to lower latency and hasten downloads. *(Image courtesy of Qualcomm)*

works will browse the internet, download files, and stream videos faster and with fewer interruptions. 5G chips might also be used to connect delivery drones, virtual reality headsets, and billions of wireless sensors—all of which need networks that respond quickly and exchange reams of data with the cloud.

As wireless connectivity shifts into almost everything, Qualcomm, the largest maker of modem chips for smartphones, is facing stiff competition from Mediatek and Samsung. Another contender is Intel, which views wireless chips as a cornerstone of its business, linking phones and sensors to servers equipped with its computer chips. Intel recently polished its modem-making reputation, selling chips to Apple for some models of the iPhone 7.

Qualcomm is trying to preserve its edge by releasing new technology before competitors. In February, it revealed the X16 modem chip that supports downloads up to 1 gigabit per second. That contrasts with the 225-megabit download speeds of the latest 4G technology, also known as LTE Advanced.

The chipmaker also said that Australia's Telstra would be the first wireless carrier to provide gigabit wireless networks, and that Netgear would build the first router equipped with the X16 modem. The Wi-Fi router will connect to Telstra's network via cellular technology instead of fiber optic cable. ■

PRINTED CIRCUIT BOARD Market Rose Slightly Last Year

FOR DECADES, CHIPMAKERS have ventured to make parts smaller, cheaper, and multifaceted. But electrical engineers are pouring vast sums into the printed circuit boards where these chips live, according to data from an industry trade organization.

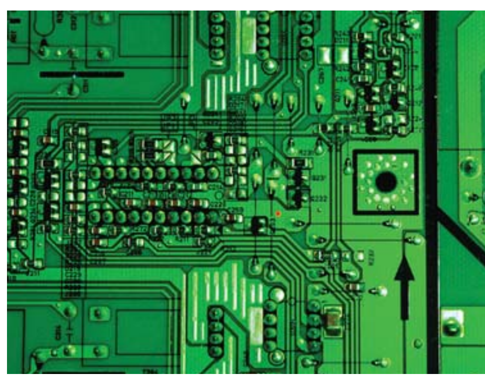
The market for printed circuit boards increased $58.6 billion last year, up 2% from 2014 after factoring in currency fluctuations, according to a report from the Association Connecting Electronics Industries.

Sharon Starr, the organization's director of market research, said that PCB companies are finding growth in spite of the larger slowdown in the electronics market. She predicted that makers of circuit boards for wearables, automobiles, and connected devices like wireless sensors, would prosper in the next few years.

The report also underlined the shifting nucleus of circuit board manufacturing. Asia now accounts for 91% of the world's circuit board production, according to the report. Among the largest companies are Taiwan's Tripod and Compeq, Japan's Meiko, and South Korea's Samsung Electro-Mechanics.

Electrical engineers are also increasingly using new types of circuit boards, the report said. The market for flexible circuit boards, which are manufactured by laying circuitry onto flexible plastics, grew significantly faster last year than rigid PCBs. Typically, the flexible boards are more expensive, but they can be twisted and curved in order to fit into awkward product shapes, like robotic arms, automotive controls, and wearable devices.

In another report, from Technavio market research, the global printed circuit board market is projected to grow at a compound annual growth rate (CAGR) of around 3% by 2020. Much of that growth is expected in Pac Asia nations, with high demand for mobile and consumer electronic devices. ■



Here is a printed circuit board with a labyrinthine array of copper wires. *(Image courtesy of Carl Drougge, Creative Commons)*

Inside TRACK with Alexander Chenakin,

Vice President, Advanced Technologies, Micro Lambda Wireless

Interview by CHRIS DeMARTINO, Technology Editor

***DR. ALEXANDER CHENAKIN**, vice president, advanced technologies at Micro Lambda Wireless Inc., is responsible for overseeing the development of advanced signal-generator products. Chenakin is well-recognized in the field of frequency synthesis. He has written more than 40 technical articles, holds two U.S. patents, and is the author of **Frequency Synthesizers: Concept to Product.** He is a senior IEEE member and has been an invited speaker for several IEEE-sponsored events.*

This is your second stint with Micro Lambda Wireless. How has the industry changed since the first time you were with the company?

Micro Lambda Wireless offers a variety of components (such as YIG oscillators, filters, and frequency synthesizers) for complex microwave subsystems and instruments. In the past, microwave instruments were built using individual connectorized modules connected with coaxial cables. The designer could easily isolate and refine individual blocks to make them perfect. These days, such complex assemblies have to be made on a common printed-circuit -board (PCB) using tiny surface-mount parts.

For example, we have a synthesizer (to be announced soon) that measures only 2.5 × 2.5 × 0.65 in., while showing quite remarkable noise characteristics (–125 dBc/Hz at 8 GHz output, 100 kHz offset). A great effort is required to minimize interactions between individual devices sitting on the same board in such a crowded space. Furthermore, many parts are reused to accomplish different functions, which are distributed through the whole assembly. The net result is a significant increase in "design density," meaning both component count and functionality per square inch. This seems to be a "must" approach these days.

When it comes to frequency synthesizers, what are some of the most demanding requirements you see today?

As a general trend, the modern equipment tends to be faster, smaller, and less expensive. For frequency synthesizers, they say "less is more," meaning lower phase noise, lower spurs, lower power consumption, and lower cost. To complete the picture, low settling time—or in other words, fast switching speed—becomes increasingly valuable as dictated by the ongoing increase of the data rates of modern microwave systems. These characteristics are easily achievable separately. However, they can represent a certain challenge if they have to be met simultaneously; that's normally the case.

Besides demanding performance characteristics, modern synthesizers are expected to provide extended functionality, such as amplitude control or various modulation formats. A very desirable function is in-phase/quadrature (I/Q) vector modulation. In the past, high-quality, test-and-measurement-grade (T&M grade) IQ signals were only available in high-end bench-top signal-generator instruments. Today, due to the rapid development of highly integrated ICs, this function can be brought to the synthesizer module level. A high-performance I/Q synthesizer is on the list of our new developments.

What are some of the most notable technology advances of the last five or 10 years with regard to oscillators and frequency synthesizers?
There are a number of outstanding products in this field acknowledged by the industry, and described in detail in *Microwaves & RF's* 50th anniversary issue featuring the most notable advances and "people who made it happen." Not trying to rank any specific developments, I would emphasize device miniaturization as a general trend that opens new horizons in the development of complex microwave solutions.

In your book, *Frequency Synthesizers: Concept to Product*, you discuss performance differences between synthesizers based on yttrium-iron-garnet (YIG) and voltage-controlled oscillators (VCOs). Can you explain some of those here?
Historically, high-performance phase-locked-loop (PLL) synthesizers have relied on YIG oscillators featuring broadband operation and excellent phase noise. YIG oscillators also offer very linear and repeatable tuning characteristics that simplify the synthesizer coarse tuning in multi-loop schemes. These unique features led to the domination of YIG-based designs in high-end applications, such as test-and-measurement signal generators. The disadvantages of YIG oscillators include high power consumption, large size, and relatively slow tuning speed.

Alternatively, VCOs tune faster—typically in the microsecond range. In addition, the size, power consumption, and cost of VCOs are generally lower compared to YIG devices. However, the noise performance of a VCO itself is considerably worse. This puts a lot of pressure on synthesizer designers to suppress VCO noise using system-level solutions, such as multi-loop, wideband PLL architectures. Nevertheless, very low phase noise (T&M grade) is achievable in VCO-based synthesizers, too.

Micro Lambda actively explores both technologies, as well as new innovative system-level solutions, to deliver the fastest tuning speed and lowest phase noise compared to the industry standards.

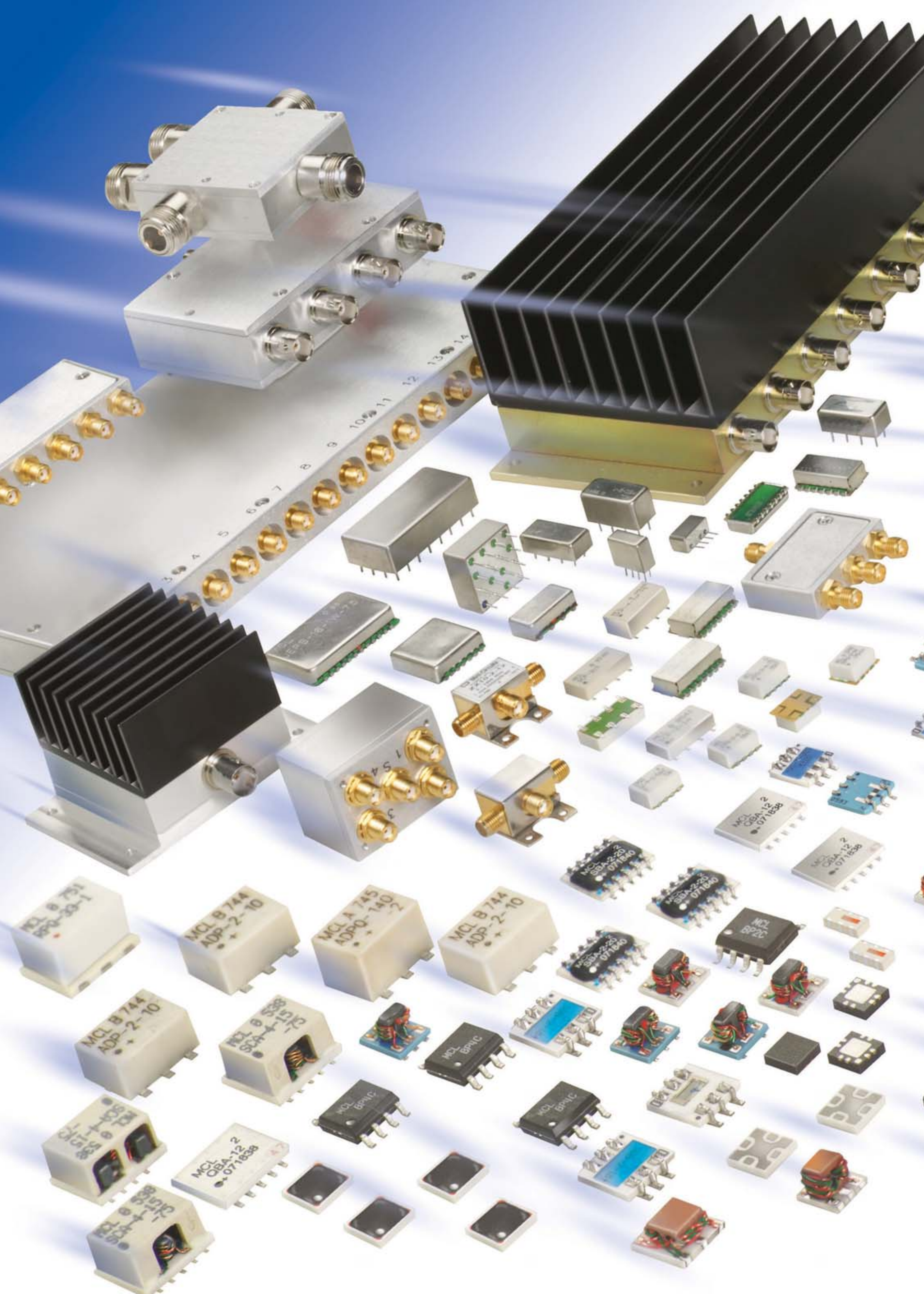
With the move to higher frequencies (i.e., 5G), what additional challenges will that present?
Millimeter-wave frequencies hold the strongest potential to power 5G wireless networks. Historically, millimeter-wave components were built using die devices and chip-and-wire technology. Expensive equipment, tight tolerances, and extensive tuning were key words in the millimeter-wave designer's vocabulary. Due to high technology costs and limited integration capabilities, such components have been mostly restricted to special applications.

However, the recent demand of low-cost, mass-production devices is drastically changing the millimeter-wave realm. Today, highly-integrated surface-mount ICs are available up to high millimeter-wave frequencies, therefore allowing complex components and subsystems to be built using low-cost PCB technologies. A frequency synthesizer—as a part of virtually any microwave or millimeter-wave subsystem—is a part of the game. We are focusing on the development of innovative millimeter-wave synthesizers up to 110 GHz to bring truly high-performance, yet affordable, alternatives to traditional solutions.

Lastly, do you see possibilities to further improve the performance of oscillators and synthesizers in the future?
Absolutely. What is a frequency synthesizer? It is a "black box" containing some circuitry that translates one (or more) input frequency—called a reference—to a number of output frequencies with desired characteristics. Thus, the input reference oscillator sets the initial frequency quality standard or expectations.

Today's commercial oven-controlled crystal oscillators (OCXOs) easily achieve phase-noise performance of −176 dBc/Hz (or better) at 10 kHz offset and 100 MHz output. This can potentially translate to performance of −136 dBc/Hz at 10 GHz, —assuming the synthesizer circuitry is "ideal." Though nothing is ideal, all current developments are chasing for such an ideality and are quite close. Direct analog and direct digital techniques have big potential here.

However, a major breakthrough is expected by using a reference with other physical principles or materials; for example, using optoelectronic methods or sapphire resonators. Phase noise of around −170 dBc/Hz at 10 kHz offset at 10 GHz output (not 100 MHz!) for a sapphire-resonator-based oscillator has been reported. These quality expectations will dramatically change conceptual approaches for building new synthesizers or even the whole way of thinking about this problem. What performance can be eventually achieved? Only the future will tell. A lot of amazing developments are expected to occur over the next decades. mw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USING SOUND WAVES TO ANALYZE MIMO

WIRELESS COMMUNICATIONS SYSTEMS must often overcome multipath propagation as part of different operating environments, and it is no different for systems equipped with multiple-input, multiple output (MIMO) antenna setups. Multipath results from radio waves bouncing off walls, buildings, and other objects between a transmitter and receiver. Studying the effects of multipath radiation is fairly straightforward with a single transmit antenna and receive antenna. However, it becomes proportionally more complex with MIMO—radio waves move between multiple antenna elements from the transmitter to the receiver and then additional beams come from reflections.

To help understand the possible multipath conditions in different radio environments, Luis Mendo of the Technical University of Madrid developed a way to study multipath in MIMO systems using sound waves from inexpensive audio speakers. By capturing sound with microphones at a mock "receiver," it then becomes possible to analyze the multipath effects with the aid of a popular math-based, PC software program.

Many of the exhibitors and visitors at the recent EDI CON 2016 in Boston spoke hopefully of their future roles in supplying components, test equipment, and engineering solutions for future Fifth-Generation (5G) wireless communications networks. Although standards have yet to be formulated for 5G wireless networks, most developers agree that MIMO techniques must handle the large amounts of data representing greater numbers of wireless communications systems users demanding more voice, video, and data communications. Use of sound instead of radio waves to experiment with different MIMO concepts provides a practical means of exploring the spatial effects of various environments and operating conditions on MIMO techniques.

One such MIMO technique is spatial multiplexing. By including multiple antennas at a transmitter and receiver, it is possible to use different beams to increase the amount of data carried between the two antennas. The authors note the two main conditions for successful MIMO spatial multiplexing: the transmitted beams should point in sufficiently different directions so that they do not overlap, and the multipath environment should provide a large number of obstacles whereby the transmitted beams can arrive at the receiver from directions that are sufficiently separated to avoid overlap. Sound waves help to simplify the analysis of an operating environment for the potential use of MIMO in a wireless network.

The test equipment is actually quite available, consisting of a pair of laptop computers with audio capabilities that are used as a receiver and a transmitter. A pair of loudspeakers is placed at the transmitter; they need not be of particularly good quality. The transmitter processing and sound generation is done with the aid of MathWorks' *(www.mathworks.com)* MATLAB simulation software. The receiver has a pair of microphones that pick up the transmitted sound waves and use a standard sound editor for recording. The saved audio files are read and analyzed with the help of MATLAB software. The test equipment for this audio version of MIMO analysis is simple and low-cost, and provides surprisingly comprehensive analysis of almost any operating environment.

See "Illustrating MIMO Transmission by Means of Sound Waves," *IEEE Antennas & Propagation Magazine*, Vol. 58, No. 4, August 2016, p. 90.

MEMS AND MICROMACHINED WAVEGUIDE COMBINE FOR 500-GHZ PHASE SHIFTER

TO INVESTIGATE THE potential of microelectromechanical-systems (MEMS) technology for terahertz applications, researchers from the KTH Royal Institute of Technology in Stockholm and the California Institute of Technology in Pasadena, integrated a submillimeter-wave, 3.3-b MEMS phase shifter in micromachined waveguide for use from 500 to 550 GHz.

The component was created by loading micromachined rectangular waveguide with nine E-plane stubs. The phase shifter uses reconfigurable MEMS surfaces to block or unblock the E-plane stubs from the waveguide as well as achieve the different phase states.

The component provides a linear phase shift of 20 deg. in 10 discrete steps (3.3 b). It features only 3 dB or less insertion loss from 500 to 550 GHz, with at most 1.5 dB attributed to the MEMS surfaces. Most of the insertion loss was traced to misalignment and mechanical manufacturing errors with the micromachined chips and the waveguide surfaces. The MEMS chips were fabricated on SOI wafers and deep-reactive-ion-etching (DRIE) process techniques. Simulations were performed with CST Microwave Studio simulation software from CST *(www.cst.com)*, and measurements were made using a PNA-X VNA system with waveguide frequency extenders from Keysight Technologies. The results were closely matched for phase shifts from 0 to 90 deg. in 10 steps across a frequency range of 500 to 600 GHz.

See "Submillimeter-Wave 3.3-bit RF MEMS Phase Shifter Integrated in Micromachined Waveguide, "*IEEE Transactions on Terahertz Science and Technology*, Vol. 6, No. 5, September 2016, p. 706.

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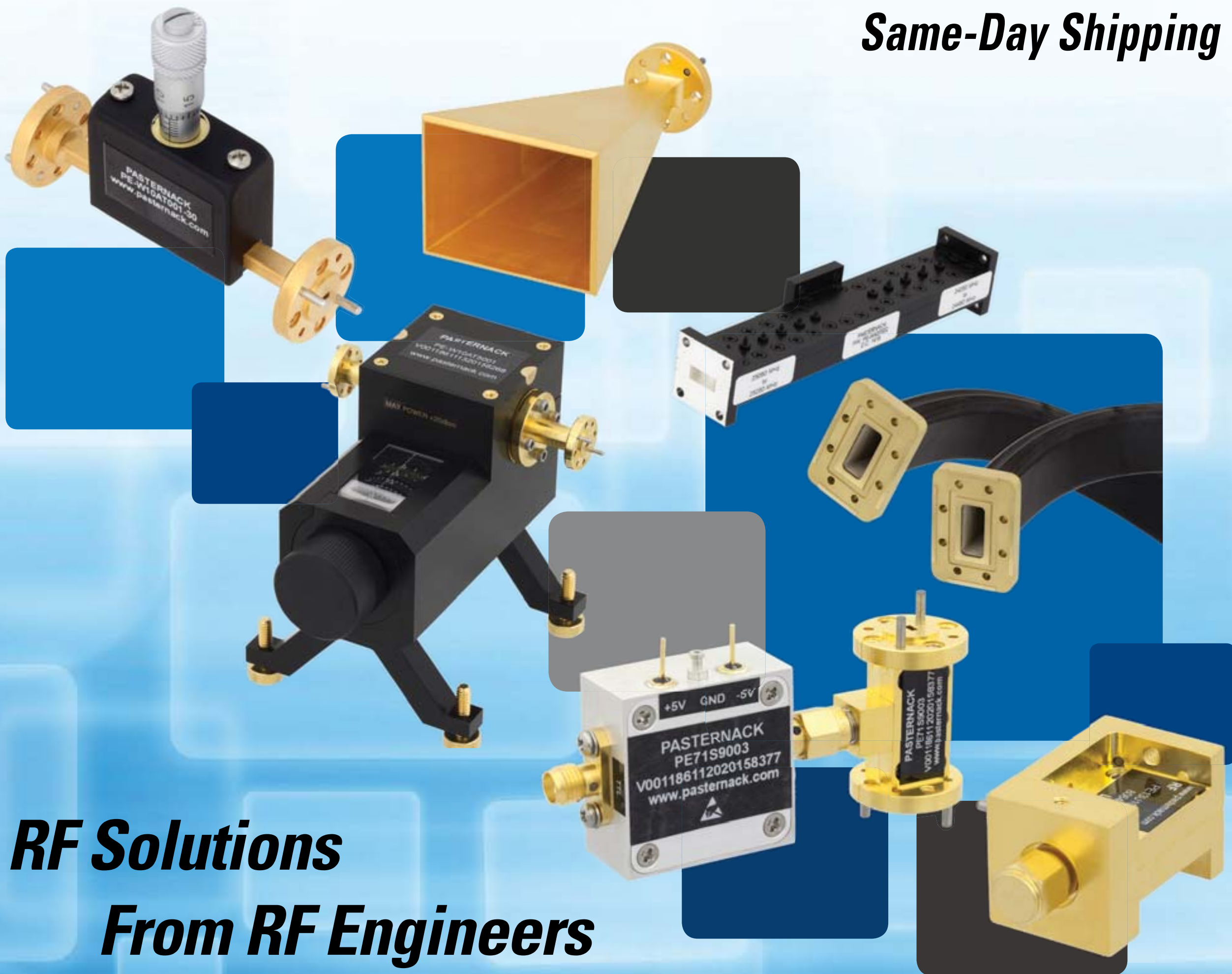

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EM Simulation Technologies Support RFIC Development

Designers of RF integrated circuits can take advantage of several different electromagnetic simulation techniques to meet today's requirements.

RF INTEGRATED CIRCUITS (RFICs) employ a variety of different interconnect and passive component geometries. Each requires specialized electromagnetic (EM) technology to provide accurate modeling in a reasonable amount of simulation run time.

For example, a transistor feed network may consist of a complex network of short traces, best modeled using quasi-static techniques for parasitic extraction. On the other hand, electrically longer structures like inter-stage transmission lines and on-chip distributed components such as spiral inductors require planar or 3D EM simulation to capture full-wave behavior. Furthermore, non-planar geometries—e.g., flip-chips, ball grids, and bond wires—require full arbitrary 3D EM simulation.

This article examines the characterization of these different RFIC structures. The EM simulation technology available in NI AWR design software, operating to support component and interconnect modeling within a typical Cadence RFIC design flow, was used.

RFICS VS. MMICS

RFICs are based on silicon or silicon-germanium (SiGe) semiconductor technology, and were originally developed for sub-microwave frequencies. These devices have significantly higher transistor densities than their monolithic microwave integrated-circuit (MMIC) counterparts, which are based on III-V compound semiconductors such as gallium arsenide (GaAs) and gallium nitride (GaN). Targeting high-volume computing and communication applications, RFICs consist of transistor arrays connected by a large number of very short electrical lines, known as "nets," in a complex network.

These nets are traditionally modeled with discrete resistance and capacitance circuit elements using quasi-static approximations to extract their parasitic effects. Parasitics degrade device performance and, therefore, must be accounted for during simulation.

In EM simulation, quasi-static approximation refers to equations that do not involve time derivatives (static), even if some quantities are allowed to vary slowly with time. The resulting mathematical models can be used to describe traces that are electrically short and thus do not produce significant amounts of EM waves. This EM technique allows designers to account for the impact on performance due to parasitics, providing modeling support for layout complexity with a tradeoff of simpler electrical models.

In contrast, MMICs, which target microwave frequencies and above, utilize traces that are not electrically short. Therefore, they require characterization that also includes their full-wave behavior.

Since the layout of the interconnect network itself is a critical part of the electrical design, accurate modeling is required from the design start. Initially modeled using distributed transmission-line theory, MMIC passive components and interconnects are frequently characterized with planar EM

EM ANALYSIS TECHNIQUES FOR IC DESIGN

Simulation technique	Simulation speed	Memory requirements	Characteristics
Parasitic extraction	Faster(est)	Low/medium	R, C, and L/transient
Quasi-static model	Faster	Low	Cross-section solver
Quasi-static method of moments (MoM)	Fast	Low/medium	Electrically small structures
Full-wave MoM	Medium	Medium	Planar 3D, sidewall currents, mesh conductors only
Finite element (FEM)	Slow	Medium	Completely general and arbitrary structures, volume mesh

Higher-fidelity modeling

simulation using method of moments (MoM) techniques. Such techniques, increasingly being integrated within RF/microwave circuit design tools, can solve large structures.

For example, recent advances in the planar EM simulator AXIEM support fast simulation run times of large networks. As a result, it is now practical to perform EM simulation on an entire MMIC layout directly within an NI AWR Design Environment, specifically Microwave Office, circuit simulation.

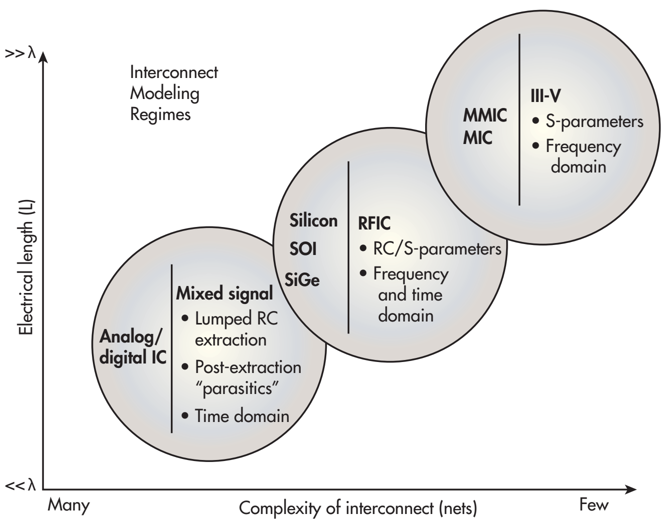
Today's RFIC designs combine MMIC and analog IC structures to achieve the high density/functionality at microwave/millimeter-wave frequencies for emerging communication and aerospace applications. A typical RFIC contains a diverse range of structures requiring electrical characterization, from relatively large spiral inductors to very small high-density interconnects.

Depending on the electrical length of the structure, critical portions of the RF interconnect network may not be adequately modeled through parasitic extraction, requiring the designer to apply full-wave EM simulation. The *table* describes various EM analysis methods available to create a layout-driven model, along with some of their high-level characteristics.

MATCH THE SIMULATOR TO MODELING REQUIREMENTS

IC modeling requirements are determined by physical length relative to the frequency-dependent signal wavelength *(Fig. 1)*. Distributed models, derived by full-wave EM simulation as opposed to quasi-static approximation, are used for microwave circuits (upper right circle), where transmission lines are electrically long and phase delay must be considered.

Simulating an entire MMIC is a tractable problem for a simulator such as AXIEM, which is capable of solving 100K or more unknowns in less than 30 minutes per frequency point



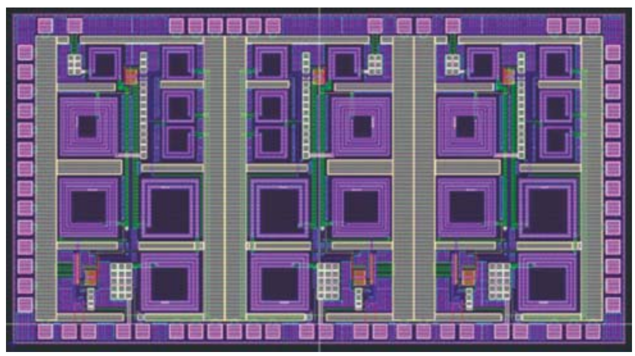
1. This illustration demonstrates how interconnect complexity is related to electrical length.

using fast solver technology. Full-wave EM simulators generate S-parameter networks to represent distributed interconnects and passive components in the frequency domain used in most RF/microwave circuit simulations.

EM simulation and modeling requirements for RFIC design fall somewhere between III-V and analog silicon ICs. One design-flow challenge involves applying the appropriate EM simulator to a diverse set of integrated IC technologies, applying parasitic extraction for the active device interconnects, and utilizing a full-wave EM tool for inductors and other structures.

Another challenge for EM simulation design flow is model partitioning. For example, *Fig. 2* shows a three-channel RFIC receiver with spiral inductors requiring a planar EM solver like AXIEM or the "Analyst" 3D finite-element-method (FEM) solver.

In this receiver, the designer may choose to model each of the matching coils individually, all of them together in a single channel, or all channels in one big simulation structure. The choice will significantly impact EM simulation speed and may or may not affect the overall accuracy, depending on the coupling that occurs between individually modeled components.



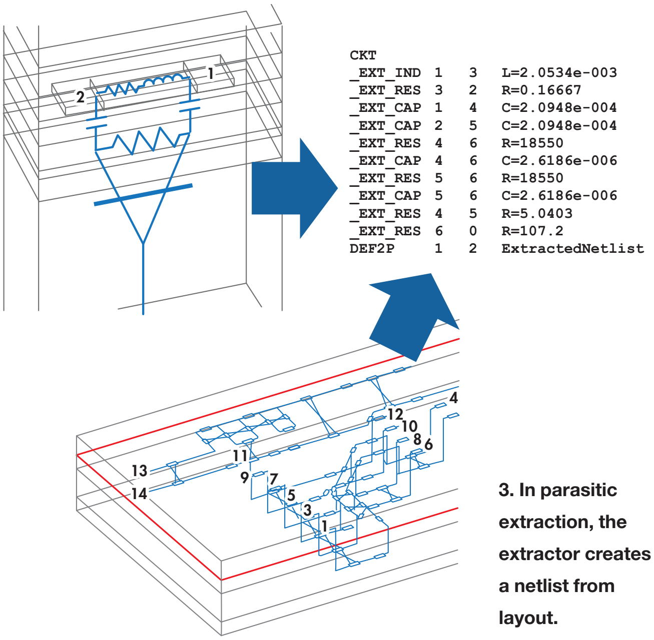
2. This RFIC is a three-channel receiver.

COMPARING EM SIMULATION TECHNIQUES

Parasitic Extraction

In traditional parasitic extraction, a netlist is created using EM quasi-static methods applied to the physical layout of the nets/traces *(Fig. 3)*. The resulting model is the resistance of each net and the self-capacitance of each net to ground. Mutual capacitances between nets can also be included.

One modeling challenge is properly identifying the ground. In general, silicon chips do not have a well-defined ground. RFIC grounds can be formed by the doped substrate of the silicon, or a specially constructed interconnect. Spirals often have a metal grid under them or a surrounding guard ring to provide a ground and associated current return path. While the extra metal adds capacitance, which affects the performance of the circuit, the explicit ground improves model accuracy, thereby reducing potential design failure. Some parasitic extractors can calculate partial inductance for higher



3. In parasitic extraction, the extractor creates a netlist from layout.

frequencies, but will yield inaccurate results unless the entire current loop is correctly defined.

Automated-circuit-extraction (ACE) technology provides circuit extraction within the NI AWR Design Environment, extracting nets as distributed models for structures such as transmission lines and vias. ACE models interconnects using a series of transmission lines, resistors, and even coupled transmission-line models for parallel traces, as shown in *Fig. 3*.

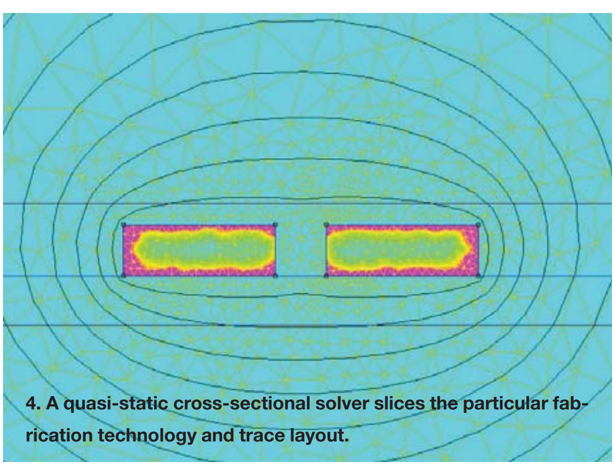
ACE extends RLGC parasitic extraction methods to support electrically longer lines for critical nets as an alternative to planar EM simulation. However, the accuracy of the extracted distributed models depends on a well-defined ground and associated current return.

Cross-Sectional (2D) Quasi-Static Solvers

A quasi-static cross-section (alternatively known as 2D) simulator solves cross-sectional slices of the IC technology's substrate and trace construction *(Fig. 4)*. This simulation technique solves for the capacitance of the structure and then calculates the frequency-dependent inductance and resistance.

Indeed, a simplified form of this type of solver is used in the static capacitance matrix in the previously mentioned parasitic extractors. The more sophisticated version shown in *Fig. 4* includes all frequency-dependent effects, such as lossy silicon substrates, and is used in some of NI AWR Design Environment's built-in silicon transmission-line models.

This fast simulator runs seamlessly in the background. Of course, the designer still can either explicitly model the interconnect as a transmission line or use ACE to extract the transmission-line models. Once created, the cross-sectional solvers ensure that the line model is accurate, provided the cross-section was accurately defined.

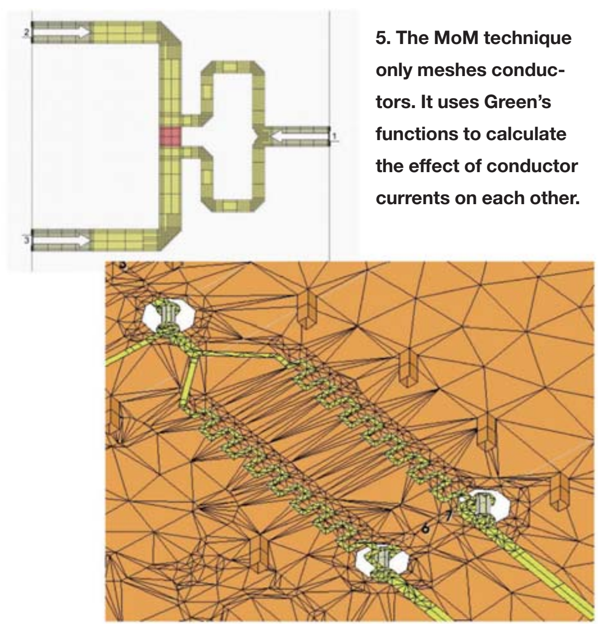


4. A quasi-static cross-sectional solver slices the particular fabrication technology and trace layout.

Method of Moments (Planar)

MoM is a frequency-domain solution that meshes conductors only and uses Green's functions to calculate the effect of conductor currents on each other *(Fig. 5)*. In RFIC applications, MoM solvers are typically used for distributed lines connected by vias, where modeling phase delay is critical. Examples include spiral inductors, branches, and discontinuities.

One consideration for MoM simulators modeling silicon is the use of aluminum for the RFIC's top metal layers. Typically, MoM simulators characterize loss using an impedance boundary condition on the surface of the metal trace. MoM simulators do not solve for currents inside the trace. This shortcoming is most critical in accurately calculating the Q of a spiral inductor. Such Q measurements thus should be performed with a full 3D EM simulator like Analyst, which will provide a mesh inside the metal and lead to a more accurate result.



5. The MoM technique only meshes conductors. It uses Green's functions to calculate the effect of conductor currents on each other.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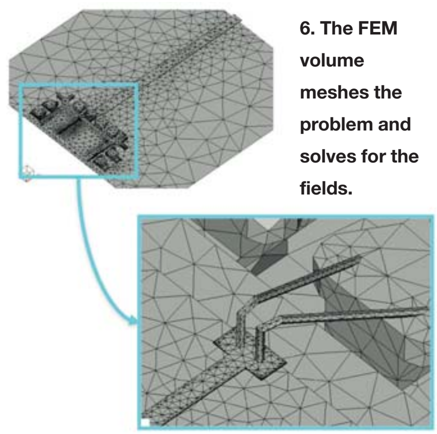
Finite Element Method (3D)

Analyst uses the finite element method to produce a volumetric mesh for solving for the electric fields using Maxwell's Equations *(Fig. 6)*. Analyst also addresses completely arbitrary structures such as wire-bond/bond-pad interfaces. However, the FEM technique takes longer to simulate and overall has the largest memory requirements of all EM simulators mentioned.

Given the complexity of RFIC design, EM simulation is most effective when integrated within a design flow that includes circuit simulation, optimization, corner/yield analysis, and process design kit (PDK) support. Designers using multiple EM techniques for model creation must be able to easily swap simulators or compare the results from different simulators to determine the best method for a given structure. Swapping various model types between extracted nets, EM-derived S-parameters, and more complicated RF models is handled in Microwave Office using the switch lists feature.

Supporting multiple EM technologies within a single project or circuit hierarchy is necessary for simulating heterogeneous RFIC structures simultaneously without having to import models from third-party EM tools. As an example, NI AWR Design Environment supports circuit co-simulation in Microwave Office (or Analog Office) with critical flip-chip transitions extracted with Analyst, spiral inductors simulated with AXIEM, and nets representing a complex transistor feed network modeled in ACE.

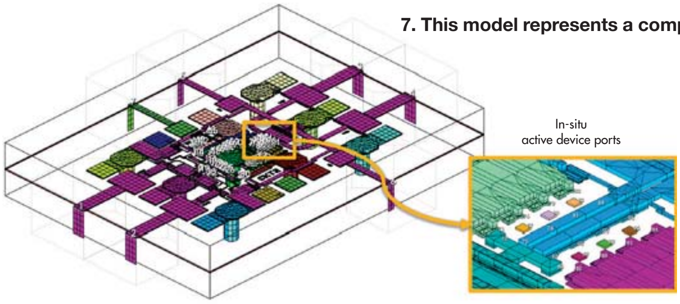


6. The FEM volume meshes the problem and solves for the fields.

CIRCUIT/EM CO-SIMULATION

Embedding layout-driven EM simulation into a circuit hierarchy that combines a model of all significant IC structures with the remaining active/passive components will provide greater accuracy for design verification. *Figure 7* shows an RFIC design verification with the active devices connected directly to the EM simulated layout using in-situ ports. This circuit setup and simulation is made possible through the internal ports and de-embedding capabilities

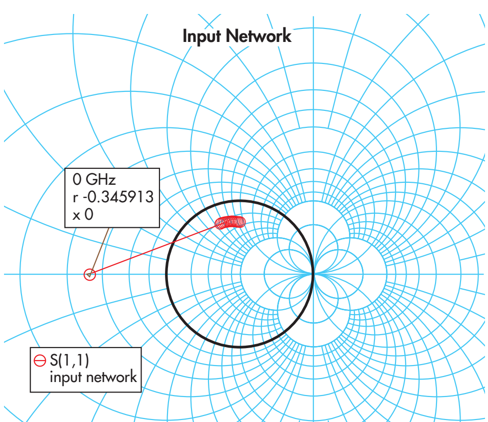
7. This model represents a complete MMIC simulation MoM example.



within AXIEM. De-embedding lines remove artificial interactions between the simulation port and nearby elements of the EM structure.

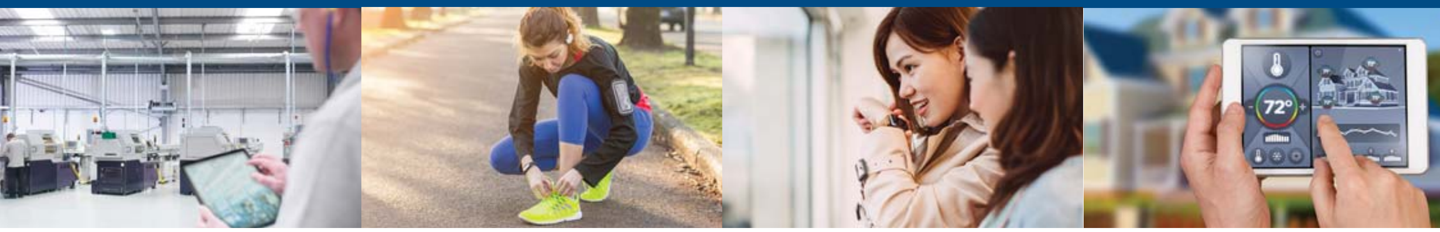
Accurate EM/circuit co-simulation requires specific capabilities on behalf of both the circuit and EM simulators. Circuit simulations for RFICs are often conducted in both the time and frequency domain. The transient circuit simulator in Microwave Office performs time-domain circuit analysis, while large-signal frequency-domain circuit analysis is performed through harmonic balance.

Accurate harmonic balance results need broadband network impedance information at all transistor nodes, including dc, excitation frequencies, and harmonic frequencies. Incorrect dc impedance will cause a transistor biasing discrepancy, while incorrectly defined harmonic terminations will impact in-band transistor results. Incorrect dc impedances occur when S-parameters are improperly extrapolated to f=0 (*Fig. 8*).



8. Large-signal simulations, such as power sweeps, require dc and harmonic information when done in the frequency domain.

Certain EM techniques, such as FEM, are ill-suited for extracting low-frequency and dc impedances. Analyst has a low-frequency limit of 10 MHz, whereas the AXIEM simulator has a built-in low-frequency solver that can address modeling problems at dc. For parasitic extraction at dc, the designer should use AXIEM, ACE, or a third-party EM solver accessed through NI AWR Design Environment's EM Socket. mw



JACK BROWNE | Technical Contributor

Wireless Technology Connects Internet to Things

Many communications technologies can be used to connect different things to the internet, but various forms of wireless links will dominate this quickly evolving space.

THE BILLIONS OF electronic devices that will comprise the Internet of Things (IoT) universe may one day tell us at a glance all we need to know. Such devices will feed data from equipment in homes, offices, warehouses, and vehicles to the internet for fast and easy access from a mobile device. While some communications systems operate with physical cables, such as landline telephone networks, cable-television (CATV) systems, and power utilities, most IoT devices and IoT networks will rely on wireless technology. The choice of wireless technology will have a great deal to do with the success of these IoT networks.

IoT technology is projected to be the basis for such phenomena as "smart cities," "smart factories," and "smart homes," where lights and appliances can be remotely programmed and controlled via their connections to the internet *(see figure)*. In these IoT networks, multiple sensors provide data on temperature, humidity, open doors, unlocked cars, and even when lights are on or off. Adding intelligence in the form of a microprocessor to each IoT sensor will allow for interaction with data from other sensors and a certain amount of decision-making.

The wireless-connectivity options for IoT are typically short-distance, low-power wireless technologies such as Bluetooth Low Energy (BLE), IEEE 802.15.4 (the ZigBee wireless standard), and the IEEE 802.11 wireless-local-area-network (WLAN) standards. Some of the concerns in applying any type of wireless technology for an IoT network include:

- Low-power consumption in support of long battery life for portable devices or devices not connected to the power grid.
- Flexibility to modify them with future advances.
- Data security from would-be hackers.

The modern automobile can be thought of as a moving sensor network. It depends heavily on multiple sensors for proper operation and, if equipped with wireless sensors as in an IoT network, lays the groundwork for a highway system that can monitor traffic conditions and fuel consumption while even improving on overall road safety.

In support of future IoT network growth, the costs of components like electronic sensors and microcontrollers are dropping. Thus, devices and components for wireless connectivity are still vital parts of expanding IoT capabilities.

Using IoT devices throughout a household allows for the creation of a "smart home," in which electronic appliances can be controlled remotely by means of a smartphone with internet access. *(Courtesy of AT&T)*

When trying to pinpoint the optimal wireless technology for an IoT application, one must consider key concerns such as data security, wireless connectivity distance (the coverage area), interference to or from other wireless devices in the area, and power consumption for battery-powered IoT devices. That said, a number of different wireless technologies are currently in use for IoT, each with its own characteristics.

WHAT ARE THE WIRELESS OPTIONS?

Perhaps the best-known wireless standards in use for IoT at present are IEEE 802.11 Wi-Fi and variations of Bluetooth, including low-power BLE. Wi-Fi wireless connections, also known as WLANs, operate at industrial-scientific-medical (ISM) band frequencies of 2.4 and 5 GHz. Wi-Fi systems are widely used in homes, factories, offices, and many public places as internet access points known as "hot spots," and represent starting points for the many internet gateways that will be needed for full IoT coverage.

For short-distance wireless connectivity, Bluetooth and BLE (IEEE 802.15.1), which operate in the same frequency range from 2.400 to 2.4835 GHz, are used in some wireless medical devices as well as in a variety of wrist- and body-worn health and fitness equipment with wireless IoT access, including "smart" watches. BLE (also known as "Bluetooth Smart") is an attractive wireless option for many of these applications due to its low energy consumption versus standard Bluetooth, although it lacks backwards compatibility with standard Bluetooth.

Another wireless candidate for IoT sensor networks is ZigBee (IEEE 802.15.4), a low-power standard developed for use in machine-to-machine (M2M) wireless networks. Along with ZigBee PRO, a version optimized for lower power consumption targeting thousands of IoT devices, these wireless standards are designed for energy consumption through low latency and low-duty-cycle operation. In fact, ZigBee PRO includes a feature known as "Green Power" that supports the use of energy harvesting in self-powered IoT devices capable of operating without batteries or power lines.

ZigBee provides global operation in the 2.4-GHz band as well as regional operation at 915 MHz in the U.S., 868 MHz in Europe, and 920 MHz in Japan. It uses industry-standard AES-128-CCM encryption for data security.

WiMAX (IEEE 802.16), short for Worldwide Interoperability for Microwave Access, is a much-longer-distance wireless transmission method than the earlier standards, providing wireless access across a radius of approximately 50 km compared to meters for the other standards. It can also transfer data at rates to 50 Mb/s and higher. WiMAX operates in licensed and unlicensed frequency bands from 2 to 11 GHz and from 10 to 66 GHz. The tradeoff for increased wireless coverage is WiMAX's higher power consumption compared to the other wireless standards.

HOPES FOR 5G

In addition to these short-range wireless standards, some of the hopes for the coming Fifth Generation (5G) of cellular wireless communications will rest on the network's capacity to handle the enormous amounts of data generated by an untold number of IoT devices. In preparation, proposed 5G systems are being designed with many performance-enhancing, capacity-boosting features to ensure robustness in an operating environment where IoT devices will not only transmit data, but in a large number of cases, expect signals back from a user.

Use of IoT devices in industrial environments is spreading rapidly, as part of a phenomenon known as the Industrial Internet of Things (IIoT). Sensors actually have been an integral part of manufacturing environments for years, helping to control vibration, temperature, even the duration of a specific manufacturing process. IIoT devices enable remote monitoring and control of manufacturing processes.

The wireless technologies noted so far are well-recognized standards with strong industry backing, but they are not the only options for IoT. For example, LoRa is a low-power wireless technology supported by a growing number of companies (over 400) in the LoRa Alliance (www.lora-alliance.org) as a potential solution for connecting IoT and M2M devices.

Designed to serve wide area networks (WANs), the LoRaWAN specification is meant to provide simple, secure wireless interconnections of IoT devices for homes, businesses, and industry with bidirectional communications capability. The infrastructure includes gateways serving as transparent wireless bridges between network servers and IoT devices.

LoRaWAN systems employ frequency shift keying (FSK) in the form of frequency hopping for reliable reception amidst radio-congested environments, with encryption for security. The IoT network operates on lower frequencies than the more-established wireless standards for enhanced range, about 15 to 20 km. The systems use unlicensed frequencies at 902 to 928 MHz in North America, 867 to 869 MHz in Europe, and 433 MHz in Asia for wide coverage areas.

OTHER IoT WIRELESS INFLUENCES

Not all IoT growth is about wireless technologies. For instance, specifications established by the Infrared Data Association (IrDA) establish a set of protocols for wireless infrared communications over short distances, including for IoT devices. Data rates exceeding 1 Gb/s are possible, depending on the modulation and coding scheme, with coverage distances of about 0.2 m for communications between two low-power IrDA devices and about 1.0 m between two standard-power IrDA devices.

In addition, the computing/processing side of future IoT networks will determine just how much human involvement will be needed in operating these networks. For example, computer giant IBM (www.ibm.com) recently announced that it will invest more than $200 million on the new Watson Internet of Things Center (in Munich, Germany). The center will be devoted to using artificial intelligence (AI) for coordinating events on various IoT networks, and designing distributed databases to work with virtual currencies for different IoT scenarios. IBM expects to invest more than $3 billion on bringing cognitive computing to IoT networks. mw

JACK BROWNE | Technical Contributor

Microwave Energy Aims to Improve Health

Medical devices are now being implanted, worn, and mounted for monitoring in homes and hospitals to provide cutting-edge health benefits via modern wireless technology.

1. Once powered by vacuum tubes, microwave ablation sources are now much smaller thanks to GaN-on-SiC semiconductor active devices. *(Courtesy of Emblation Microwave)*

MICROWAVE TECHNOLOGY HAS long been a powerful partner to medical professionals for the treatment of different types of cancerous and noncancerous tumors. The application of electromagnetic radiation (EM) at typically unlicensed frequencies (such as 915 and 2450 MHz) provides a minimally invasive method of shrinking tumors by means of localized dielectric heating of the water content of tissue masses.

This technique, known as microwave ablation, has served many different medical areas, including cardiology, gynecology, rhizotomy, and even in some dental treatments. It represents a realistic treatment option for patients considered high surgical risks.

Microwave ablation is a mature technology, and just one of the ways in which RF/microwave energy currently contributes to improved health. The technology has cleared countless lung, liver, and prostate tumors, and spurred the growth of an equipment industry for high-power medical ablation sources, such as the model MSYS245 microwave generator from Emblation Microwave *(www.emblationmicrowave.com)*.

The compact source *(Fig. 1)* is capable of 100 W output power with pulse-width modulation (PWM) at 2.45 GHz. It represents a departure from earlier, larger magnetron-based microwave ablation sources, using solid-state amplification. The source employs gallium-nitride-on-silicon-carbide (GaN-on-SiC) transistors to provide the generous output power needed for dielectric tissue heating.

Medical ablation is also performed at lower frequencies, known as RF ablation, and at higher frequencies from 5.8 to 10.0 GHz. Use of lower-frequency electromagnetic (EM) energy for heating of bone and tissue relies on a conductive path, with access to the area to be treated. In contrast to microwave ablation, which employs an antenna to direct higher-frequency signals around an area of interest, RF ablation will channel lower-frequency energy to a relatively small volume of bone or tissue for heating. With higher-frequency microwave ablation, application of heating EM energy with minimal penetration of a target is possible, making it quite an effective tool, for example, for skin-based ablation treatments.

TRAVELING WITH TELEMEDICINE

Wireless technology has played a growingly important role in modern medicine—the combination of which is known by the general term "telemedicine." Prior to current invasive and noninvasive medical applications for monitoring organs and health conditions, the medical exploits of low-power wireless signals came in the form of radio-frequency-identification (RFID) technology to help label both medicines and patients.

The cost of RFID integrated circuits (ICs) has dropped dramatically during the past decade, allowing their use throughout the healthcare industry at a number of different frequencies. Frequency depends on location—HF tags are typically used at about 27 MHz with only microwatts of power, for a read distance of only about 3 in., and UHF tags work with milliwatts of power from 902 to 928 MHz in North America for longer read distances. Companies such as Vizinex RFID *(www.vizinexrfid.com)*, specializing in custom medical RFID products, offer design capabilities to add RFID to different medical products and equipment, including for tracking the whereabouts of mobile medical equipment.

Although adoption of RFID technology by the healthcare industry has been relatively slow, using RFID techniques with electronic product codes (EPCs) can simplify the management

of medical items throughout the healthcare supply chain. Use of RFID codes can also carry details on the regulatory requirements of different pharmaceutical products and help prevent tampering with, and counterfeiting of, legitimate pharmaceutical products.

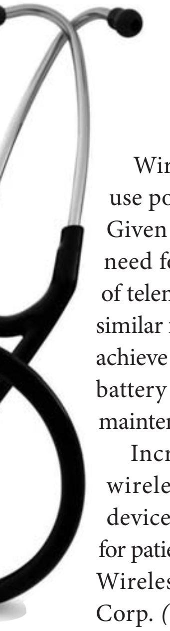
Many current efforts in telemedicine seek to replace wires in monitoring devices with wireless approaches. For example, STMicroelectronics *(www.st.com)*, working with wireless-disposable-patch developer HMicro, recently announced a single-chip wireless solution for disposable, clinical-grade wearable biosensors that can replace wires in electrocardiograms and vital-sign monitors. Designed for high-volume telemedical applications, the model HC1100 clinical transceiver chip targets wired wearable sensors and is well-suited for Industrial Internet of Things (IIoT) applications.

The silicon IC is based on WiPoint technology developed by the two companies. Each chip contains a trio of low-power radios, covering Wi-Fi, ultrawideband (UWB), and medical-band (MBAN) frequency ranges. A single chip also boasts multiple sensor interfaces, a dual-core ARM Cortex M0 microprocessor, 352-kb random-access memory (RAM), and power-management circuitry. The multiple sensor interfaces support monitoring of heart rate, blood oxygen levels, and respiration, and can interface with microelectromchanical-systems (MEMS) microphones and motion detectors in the study and tracking of patient behavior.

OTHER WIRELESS BREAKTHROUGHS

Harvard University has been active in recent years in applying modern electronic technology to medical solutions, typically motivated by replacing wires where possible in different treatments. The university has developed a number of low-power implanted electronic devices, such as cardiac pacemakers and defibrillators, working within the medical-implant communications service frequency band from 402 to 405 MHz.

The school's researchers recently received approval from the United States Department of Health and Human Services *(www.hhs.gov)* to license a wireless implantable cardioverter-defibrillator (ICD). The ICD could prove to be a boon for patients at risk of infections from wires implanted in or near the heart (for wired versions), or patients that may be in danger from narrow or blocked coronary veins.



2. Basic medical tools such as stethoscopes can also benefit from modern wireless technology. *(Courtesy of Littman, brand of 3M Healthcare)*

Wireless technologies for medical applications typically use power efficiently, such as Bluetooth Low Energy (BLE). Given the decreasing costs of BLE transceiver ICs and the need for reliable wireless connections to growing numbers of telemedical sensors in hospitals and similar facilities, BLE-based sensors can achieve extended operating lifetimes on battery power for low-maintenance or maintenance-free use.

Increased integration of standard wireless technologies into medical devices has led to enhanced mobility for patients. One example is the LifeSync Wireless ECG System from LifeSync Corp. *(www.lifesynccorp.com)*, a basic electrocardiogram (ECG) that communicates data to medical staff by means of Bluetooth technology. It can collect patient ECG and respiratory data and transmit using two-way Bluetooth channels. It is meant to complement existing, traditional ECG monitors in hospitals and other healthcare facilities, and can provide continuous monitoring even in busy environments.

To attain the electronic functionality within such medical devices, IC developers are carefully listening to the needs of the medical community. As an example, the recently announced model AD8233 heart-rate monitor from Analog Devices *(www.analog.com)* packs multiple filters and amplifiers within a wafer-level chip-scale package (WLCSP) measuring just 2.0 × 1.7 mm. Designed for wearable medical products, the low-noise IC contains a fully integrated single-lead ECG and is able to operate with a mere 50-µA typical quiescent supply current. Featuring 80-dB common-mode rejection from dc to 60 Hz, the IC is powered by a single voltage supply (e.g., a battery) of +1.7 to +3.5 V dc.

Even the most basic medical diagnostic tools, such as a stethoscope, can even benefit from wireless technology. Using on-board recording and Bluetooth technology, the model 3200 electronic stethoscope *(Fig. 2)* from Littmann *(www.littmann.com)*, a brand of 3M Healthcare) redefines the capabilities of a stethoscope—it's able to wirelessly transfer sounds of the heart and other organs to a computer with software for analysis. When teamed with the appropriate software, the stethoscope can visualize different body sounds in the form of computer files that are subsequently transferred electronically to colleagues for analysis. mw

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LDMOS RFICs Gain Ground in Small Cells

Advances in silicon LDMOS technology and device packaging have converged to create miniature RFICs capable of meeting the signal-amplification needs of small cells in wireless systems.

Cellular wireless-communications-link handsets and their users throughout the world are often located by large base stations, and transmissions from those base stations are typically powered by discrete silicon LDMOS RF/microwave power transistors. But with increasing use of smaller cells to provide wireless coverage at the edges of large cells—in shopping centers, airports, and other public places—LDMOS RF integrated circuits (RFICs) are supplying the transmission power rather than discrete devices.

These rugged RFICs have benefited from advances made in discrete silicon LDMOS devices. Now they can provide the transmit power levels needed by small cells, while at the same time meet the tight space and power requirements of those compact wireless cells.

Commercial silicon LDMOS RFICs, such as the Airfast family of devices developed by NXP Semiconductors (www.nxp.com), are capable of output-power levels from 5 to 500 W per device at frequencies from 728 to 2,700 MHz. Advances in this technology have moved it beyond the limits of several years ago—such as top operating frequencies of 2 GHz—to achieve impressive power levels at frequencies to 2.7 GHz and devices with usable performance at frequencies as high as 3.8 GHz, or at frequencies beyond those used by any wireless carrier.

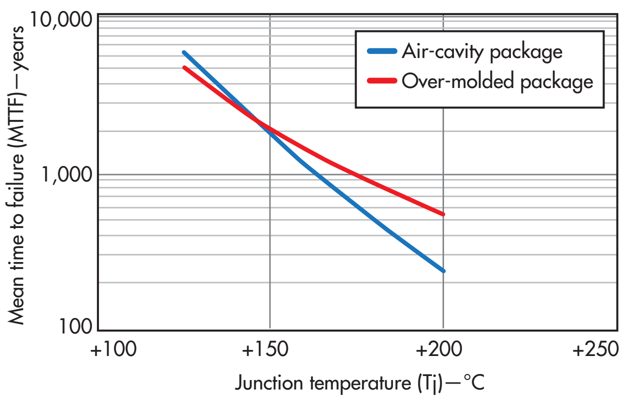
RFIC ADVANTAGES

One of the greatest benefits of an RFIC compared to a discrete transistor is the integration of the carrier and peaking stages of a Doherty amplifier within a single package. Matching circuitry is implemented on the RFIC semiconductor die rather than externally, such as on the printed circuit board (PCB) on which a discrete transistor is mounted, to reduce size and cost.

Of course, the package must be able to protect the RFIC as well as effectively dissipate excess heat from the device, and overmolded plastic packages have been significant contributors to the high levels of performance now possible with silicon LDMOS RFICs. While it might seem logical that a package made from ceramic should be more rugged and potentially have better performance than one made of plastic, just the opposite is true even at high RF power levels.

These plastic-package benefits are achieved in several ways with LDMOS RFICs, as well as discrete LDMOS transistors from NXP Semiconductors. First, the RFIC or transistor die is mounted on a copper heat spreader instead of a copper-based laminate. Since copper has high thermal conductivity of 350 to 400 W/m-K, it can reduce thermal resistance by 20% compared to a high-power RFIC or discrete device operating at the same output-power level and housed within a ceramic package with copper-topped laminate.

Lower thermal resistance allows more RF/microwave power to be handled than with an air-cavity package of the same size.



1. These test results compare a silicon LDMOS RFIC in a plastic package and one housed in a ceramic air-cavity package, to show the longevity of the latter, especially at higher junction temperatures.

This has been demonstrated at NXP by comparing one of the firm's high-power Airfast LDMOS discrete devices housed in a plastic package to the same power transistor mounted in an air-cavity housing. For the same test frequency, the power transistor mounted in the plastic Airfast package produced 282 W output power at 1-dB gain compression, while the power transistor in the air-cavity housing produced only 260 W output power at 1-dB compression.

Designers of high-power PCBs are well aware of the importance of a laminate's coefficient of thermal expansion (CTE) and how it compares to that of other materials, such as copper, that are used with the PCB dielectric material. This is a measure of how a material alters dimensionally with changes in temperature—notably, how much expansion takes place at elevated temperatures that, in a high-power transistor or RFIC, stem from the semiconductor device itself.

The copper heat spreader used in the Airfast device package reduces mismatches between the CTE at the solder joint between the package leads and the PCB, as well as between the heat spreader and the coin or pallet upon which it is soldered. Since gold metallization is not required with ceramic packages or with plastic Airfast packages, it eliminates problems caused by gold embrittlement of the solder joint.

In addition, the very tight dimensional tolerances achieved in plastic-packaged Airfast LDMOS RFICs results in excellent device-to-device repeatability. This provides, for example, consistent amplitude and phase performance for small cells using these silicon LDMOS RFICs for wireless signal amplification.

At one time, plastic packages were assumed to lack the long-term reliability of ceramic housings, but that is not the case with these advanced Airfast LDMOS RFIC packages. More than 3.5 million device test hours have been logged by NXP Semiconductors at various maximum junction temperatures for overmolded plastic packages, and 3 million test hours for air-cavity metal-ceramic packages.

Failure in time (FIT) and mean time to failure (MTTF) of both package types are nearly 1,900 years at a maximum junction temperature of +150°C *(Fig. 1)*. Plastic packages maintain good longevity at higher junction temperatures.

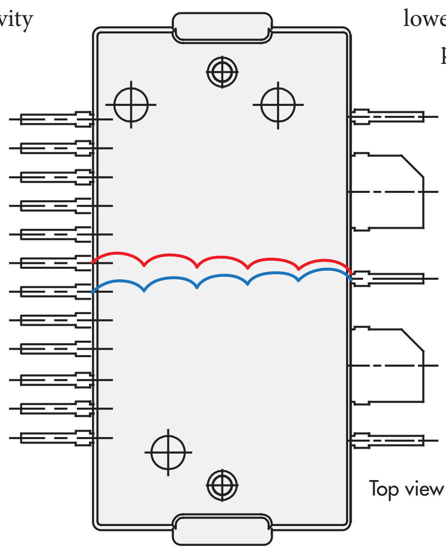
Wireless applications for LDMOS RFICs require circuits capable of handling ever-wider bandwidths. As wireless communications networks evolve, they follow a trend of consuming wider bandwidths because of the growing number of users and the ways in which they use their wireless devices. Higher data rates are needed for the increased transmission of streaming video, which has become the greatest contributor to network traffic.

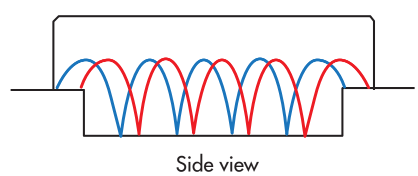
For example, the current generation of Long-Term-Evolution (LTE) cellular communications uses signal bandwidths as wide as 100 MHz. By 2020, or when Fifth-Generation (5G) wireless communications systems are deployed, the consumed bandwidth will have grown to 400 MHz or more. To put this in perspective, signal bandwidths in Second-Generation (2G) wireless networks were 5 MHz, reaching as wide as 40 MHz in the initial versions of LTE systems.

Addressing these challenges begins at the device level, where parasitic capacitance and its relationship to inductance affect a device's signal bandwidth. The drain-source capacitance at the output of an LDMOS field-effect transistor (FET) combines with the inductance of the circuit board and the wire bonds used to attach the device to surrounding circuitry, resulting in resonances. Reducing the physical distance between interconnections, however, lowers the inductance (and resulting resonant effects) and increases the signal bandwidth of an RFIC's active device.

In an Airfast LDMOS RFIC, this is accomplished by the addition of leads, bringing the FET electrically closer to the surrounding circuitry. This approach provides dramatic results, yielding signal bandwidths for a given device that are double those achieved with conventional device packaging. Development efforts show that bandwidth can be increased even further in the future to at least 200 MHz through this and other techniques, along with digital predistortion (DPD).

Achieving high isolation between in-package Doherty amplifiers is especially challenging, since its carrier and peaking (first- and second-stage) amplifier circuits are extremely close together in a miniature RFIC. The close proximity and high gain of these amplifier stages inevitably leads to crosstalk. Such crosstalk must be reduced to the lowest possible level, otherwise it will degrade performance of one or both amplifiers and linearization with DPD circuits will be more difficult.





2. This wire-bond fence provides significant isolation between the carrier and peaking amplifiers. It captures the energy generated by the amplifiers and their associated wire bonds and flows it to ground.

Current plastic-packaged devices can cover extremely broad frequency ranges while delivering considerably better performance than those in air-cavity ceramic packages.

AIRFAST ADVANCES

NXP developed a proven method for increasing isolation and reducing crosstalk, and implemented it for the first time in the company's second-generation Airfast LDMOS RFICs. This technique, called a wire-bond fence, is an enhanced grounding structure that essentially stabilizes device package electrical connections. It is placed between the amplifiers and connected to grounding pins added to the input and output of the package *(Fig. 2)*. The result is increased isolation between amplifier stages and an improvement in linearized adjacent-channel power (ACP) of 6 to 10 dBc.

Enhancements to Airfast LDMOS RFICs are evident when comparing first-generation TO-270WB-14 and second-generation TO-270WB-17 packages *(Fig. 3)* from Freescale Semiconductor. In the latter, two pins were added to the lead frame, one originating at the device input and one from the device output, both of which terminate at ground on the board. This configuration, along with the wire-bond fence, together increase signal bandwidth and isolation between carrier and peaking amplifiers, as well as increase the frequency range of the RFIC. The output leads are spaced farther apart, too, which also increases isolation.

Furthermore, the new package saves board space by using dedicated dc bias leads instead of the large quarter-wave bias line present on first-generation Airfast devices. This saves between 30 mm 2 and as much as 90 mm 2 of circuit board space, depending on operating frequency. It also plays a role in broadening signal bandwidth.

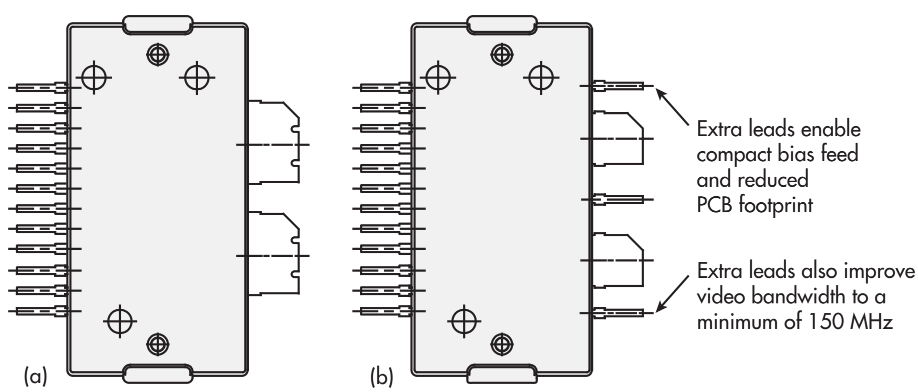
On top of that, second-generation Airfast RFICs also make impedance matching easier and provide greater flexibility for optimizing performance at specific frequencies. For example, as the input of Airfast RFICs is internally matched to 50 Ω and blocked with a capacitor, input impedance matching is not required. The devices' output impedance has been increased to between 4 and 10 Ω, higher than the 1 to 2 Ω typical of a discrete device and closer to the 50-Ω characteristic impedance of the surrounding circuitry.

Narrowing the impedance "gap" between the device and circuit simplifies design. Matching components embedded in the devices are optimized using electromagnetic simulation tools to improve quality (Q) factor and thus minimize losses, while also eliminating the inevitable variations that occur when using external matching components.

In some parts of the world, cellular networks operate over an extremely wide range of frequencies, from about 700 MHz to 3.8 GHz, requiring several amplifiers to achieve necessary signal transmission strength over such wide bandwidth. If possible, reducing the number of amplifiers can produce major cost savings while simplifying system design and reducing power consumption and size.

Currently available (second-generation) silicon LDMOS Airfast RFICs operate over multiple adjacent frequency bands, such as those from 703 to 960 MHz or 1,805 to 2,170 MHz. Meanwhile, a single LDMOS RFIC (model AFT27007N) can cover the range from 728 to 3,600 MHz.

LDMOS RFICs have significantly advanced in almost every respect within the last five years to address the demands of current cellular wireless communications systems, as well as to serve the expected needs of future systems. Current plastic-packaged devices can cover extremely broad frequency ranges while delivering considerably better performance than those in air-cavity ceramic packages. They can also accommodate very wide signal bandwidths and are achieving higher and higher levels of functional integration. There is little doubt that the performance of RFICs will keep pace with the continuing challenges posed by more complex networks. mw



3. For improved thermal management of silicon LDMOS RFICs, the design of (a) a TO-270 device package was improved in (b) a TO-270WB-17 housing with extra leads and wider spacing of the output leads.

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Dual-Band Divider Has Rejection Band at 5 GHz

This compact power divider passes signals from 1.0 to 4.8 GHz and from 6.2 to 9.0 GHz, in addition to including a rejection band to stop WLAN interference from 5.0 to 5.8 GHz.

This compact dual-band ultrawideband (UWB) power divider is designed for multiband orthogonal frequency division multiplexing (OFDM) from 1.0 to 4.8 GHz and for direct sequence ultrawideband applications from 6.2 to 9.0 GHz. It also provides a sharp rejection band from 5.0 to 5.8 GHz to help suppress interference between wireless local-area networks (WLANs) and UWB communications systems.

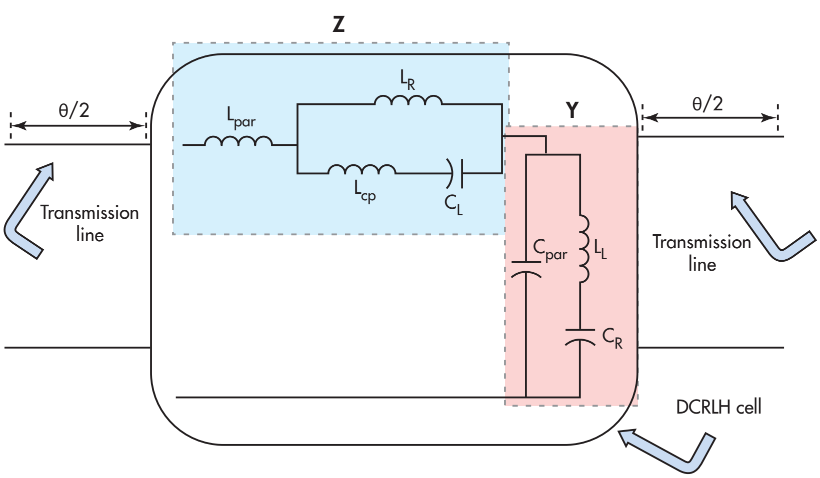
The power divider, which is based on two unit cells formed of dual composite right/left-handed microstrip transmission lines, exhibits low insertion loss in both passbands. The circuit measures just 16.6 × 20.0 mm^2—some 45.37% smaller than conventional single-band, quarter-wavelength ($\lambda_g/4$) power dividers.

Global expansion of wireless services and systems has driven the need for miniature high-frequency components operating in specific multiple frequency bands, using straightforward design approaches and ease of fabrication.[1-3] The use of metamaterials (engineered materials) has made possible the use of new design methods for improved electrical performance in smaller components.[4,5]

One of these structures is the dual composite right-/left-handed metamaterial transmission line (D-CRLH TL).[6] D-CRLH TLs have been implemented recently in a number of different configurations, yielding good results.[7-10] These planar circuits are fairly simple to realize since they do not require viaholes for ground or circuit connections.

D-CRLH TLs exhibit dual propagation passbands: a right-handed (RH) band at lower frequencies and a left-handed (LH) band at higher frequencies. The circuitry also features a nonlinear phase coefficient through the two bands, making the technology suitable for the design and fabrication of a variety of different microwave components.[11-17] One challenge inherent to the use of D-CRLH TLs, however, lies in achieving effective impedance matching over the wide frequency bands provided by the transmission lines.

Since power dividers are so widely used in high-frequency systems with other RF/microwave components—such as power amplifiers, quadrature frequency mixers, modulators, and phased-array antennas—many researchers attempt to improve these components by reducing the size of impedance transformers for them.[18-20] Some attempts at designing dual-band and wideband power dividers have employed metamaterial structures[21-23] in addition to other approaches.[24-28]



1. This equivalent circuit represents the D-CRLH unit cell.

The use of D-CRLH TLs in a microstrip configuration can deliver an extremely broadband two-way, dual-band power divider with fairly consistent performance across its full range of passband frequencies. It offers similar performance across its low-frequency band from 1.0 to 4.8 GHz for MB-OFDM systems and across its high-frequency band from 6.2 to 9.0 GHz for DS-UWB systems.

At the same time, the power divider achieves high isolation in the range of frequencies between the two communications bands, with better than 20-dB rejection of signals in the range from 5.0 to 5.8 GHz, for effective suppression of possible interference from WLAN sources.

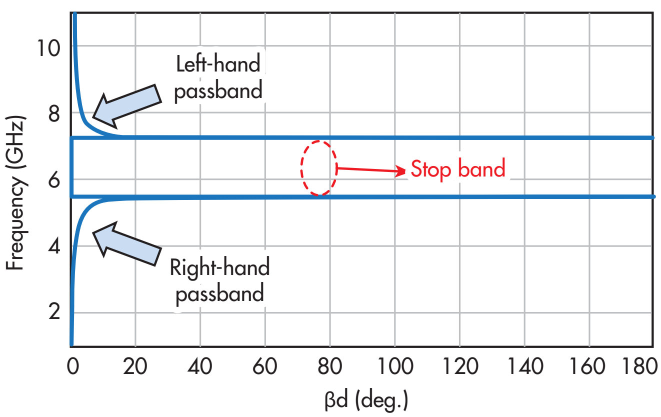
Figure 1 shows an equivalent circuit of a D-CRLH TL structure. The circuit consists of a series tank circuit formed with capacitor C_{par} and inductor L_L in series with capacitor C_R. Another tank circuit is formed by capacitor C_L and inductor L_{cp} in series with capacitor C_L. Inductor L_{par} is connected to represent any RH parasitic inductance. The tank circuit is connected to a host transmission line with electrical length θ. The phase along the D-CRLH TL (β_d) can be extracted by applying a periodic analysis of an infinite number of cells, as shown in Eq. 1[5]:

$$\cos(\beta_d) = \cos(\theta) + 0.5[ZY\cos^2(\theta/2)]$$

$$+ i(0.5)(Z_0Z+Y_0Y)\sin(\theta/2) \quad (1)$$

where Z_0 and Y_0 represent the RH characteristic impedances and admittances, respectively; Z is the series branch impedance; and Y is the shunt branch admittance. Modeling the D-CRLH unit cell as a transmission line, its characteristic impedance can be extracted by applying Eq. 2:

$$Z_{CRLH} = (Z/Y)^{0.5} = (j\omega L_{par} + \{[j\omega L_R(1 - \omega^2L_{cp}C_L)]/ [1 - \omega^2(L_{cp} + L_R)C_L)]\}/\{[j\omega(C_R + C_{par}) - j\omega^3C_{par}C_RL_L]/(1 - \omega^2L_LC_R)]\})^{0.5} \quad (2)$$



2. This is a dispersion diagram for the 70.7-Ω D-CRLH impedance transformer used in the power divider.

Design requirements for the impedance transformer include: (1) adjusting the cutoff frequencies to be the lower and upper frequencies of the two desired passbands bands; (2) achieving ±90-deg. progressive phase shifts at the start and end frequencies of the two passbands; and (3) maintaining good impedance matching within the two passbands.

Since the D-CRLH TL circuit is unbalanced, the cutoff frequencies of the middle stopband (4.8 and 6.2 GHz) were designed according to Eq. 1, such that for very small values of θ, the condition $\beta_d = \pi$ is satisfied at the two cutoff frequencies by Eq. 3:

$$-4 = \{[j\omega L_R(1 - \omega^2L_{par}C_L)]/[1 - \omega^2(L_{par}C + L_R)C_L]\} \times \{[j\omega(C_R + C_{par}) - j\omega^3C_{par}C_RL_L]/(1 - \omega^2L_LC_R)]\}\pi_{|f = 4.8\text{ GHz}, 6.2\text{ GHz}} \quad (3)$$

The upper cutoff frequency of the second passband (11 GHz) was achieved by satisfying the condition βd = 0 in Eq. 1 for small θ and a minimum (min) frequency of 11 GHz. This can be expressed mathematically by Eq. 4:

$$\min((1/2\pi)\{[1 + (C_{par}/C_R)]/C_{par}L_L\}^{0.5};$$

$$(1/2\pi)\{(L_R + L_{par})/C_L[(L_RL_{CP} + L_{par}(L_R + L_{CP})]\}^{0.5}) = 11\text{ GHz} \quad (4)$$

For effective quarter-wavelength impedance transformations over both passbands, the D-CRLH TL circuitry was designed for −90 deg. at 4.8 GHz (the edge of the RH passband) and +90 deg. at 6.2 GHz (the beginning of the LH passband). These goals can be expressed by Eq. 5:

$$\phi_{DCLRH} = \beta_{d|f = 4.8\text{ GHz}} = -\pi/2,$$

$$\phi_{DCLRH} = \beta_{d|f = 6.2\text{ GHz}} = \pi/2 \quad (5)$$

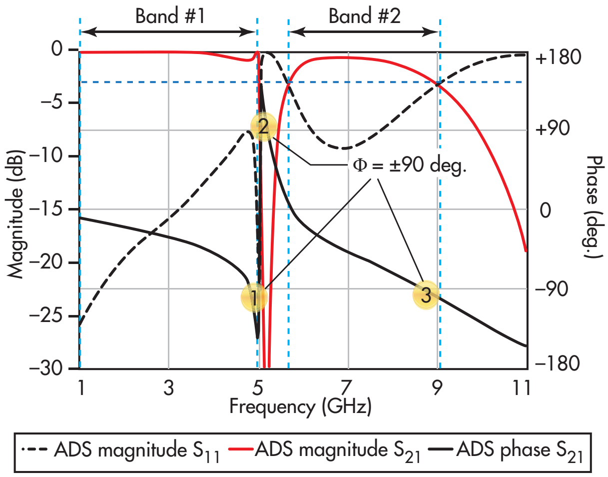
TABLE 1: LOADING ELEMENT VALUES AND DIMENSIONS OF THE D-CRLH UNIT CELL

Circuit element	Electrical values	Dimensions	Values (mm)
C_L	0.16 pF	L	4.85
L_R	2.11 nH	W	3.416
L_{par}	0.830 nH	W_i	0.2
L_{CP}	3.86 nH	L_i	3.35
C_R	0.23 pF	S	1.3
C_{par}	0.032 pF	L_L	0.3
L_L	0.30 nH	L_C	3
		W_L	2
		W_C	3

Impedance matching is adjusted by maintaining the D-CRLH transmission line with an impedance Z_{DCRLH} of 70.7 Ω near the two passband cutoff frequencies, as shown in Eq. 6:

$$\max(|\Gamma|) = 0.316|_{f = 6.2\ GHz};$$

$$\Gamma = (Z_0 - Z_{DCRLH})/(Z_0 + Z_{DCRLH}) \quad (6)$$

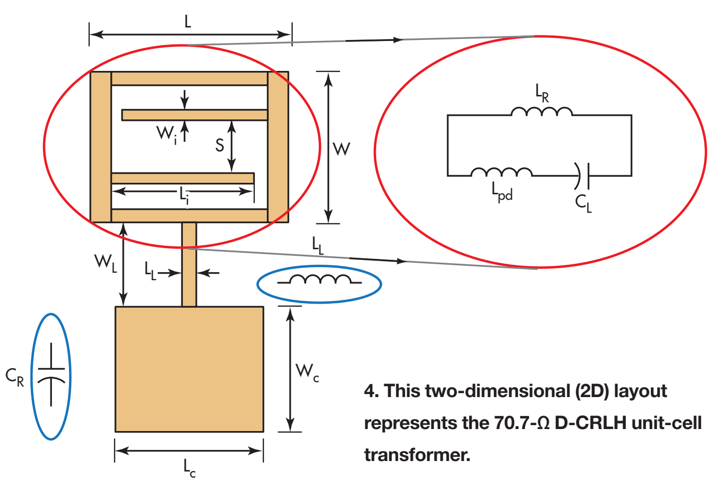


3. The plots show circuit and full-wave simulated transmission-coefficient (S_{21}) magnitude and phase for the 70.7-Ω D-CRLH unit-cell transformer.

Equations 3-6 were solved numerically using MATLAB simulation software from MathWorks (www.mathworks.com), with results presented in *Table 1*. The cutoff frequencies were validated by plotting the dispersion diagram for the calculated values using Eq. 1, as shown in *Fig. 2*. As can be seen from Fig. 2, the D-CRLH cell achieves a RH passband from dc to 5.7 GHz, and a sharp stopband from 5.7 to 7 GHz, followed by a LH passband from to 7 GHz to beyond 11 GHz.

These cutoff frequencies fulfill the design specifications for the power divider's first passband band (dc to 4.8 GHz), while the performance of the second passband is shifted by approximately 1.5 GHz. This can be considered a limitation of the numerical solution, which will be optimized during the cell realization phase of the design process.

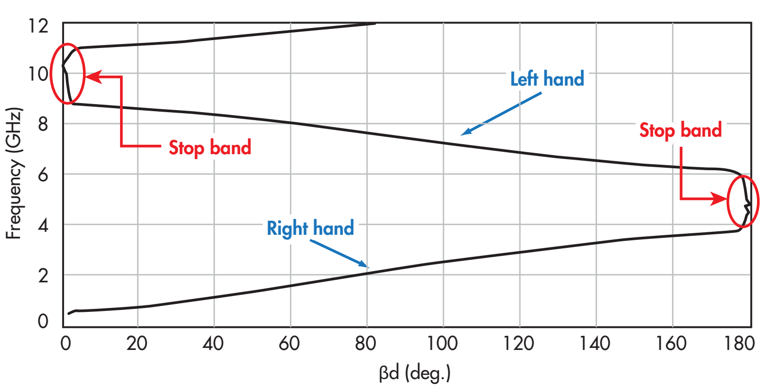
Circuit simulations on the transmission lines and power-divider circuitry were performed with the Advanced Design System (ADS) software from Keysight Technologies (www.keysight.com); simulated transmission and reflection coefficients are plotted in *Fig. 3*. The cell was terminated in 70.7 Ω at both ends during the simulation.



4. This two-dimensional (2D) layout represents the 70.7-Ω D-CRLH unit-cell transformer.

The simulations reveal the two passbands defined according to 3-dB $|S_{21}|$ cutoff points from 1 to 5 GHz and from 5.8 to 9.1 GHz. Within the first passband, $|S_{21}|$ is extremely minimal, from 0 to −0.2 dB, with very low reflection coefficient $|S_{11}|$ of −10 to −26 dB.

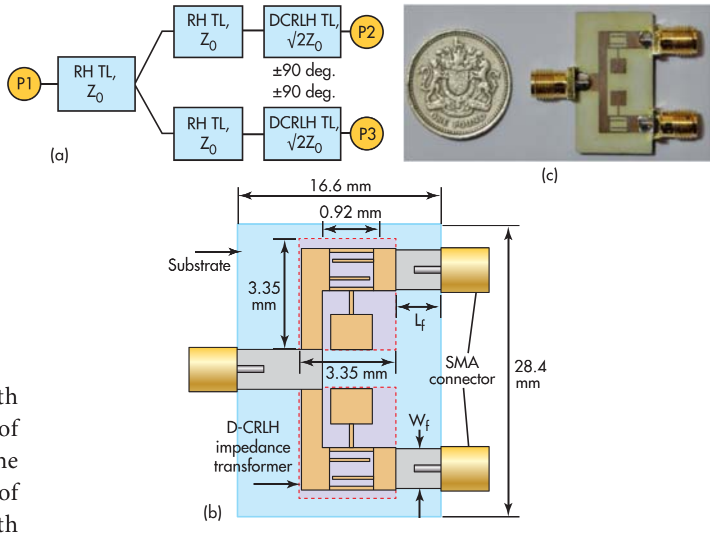
The second passband has lower $|S_{21}|$ values, −1 dB at the lower frequencies and dropping to −3 dB at the higher frequencies. The ±90-deg. phase conditions are validated by plotting the magnitude and phase of $|S_{21}|$ as shown in *Fig. 3*. As can be seen, the progressive phase is ±90 deg. within the passband at 4.85, 5.4, and 8.85 GHz. The second phase at 5.4 GHz is a bit shifted due to oversimplification of the circuit model.



5. This is a dispersion diagram of the 70.7-Ω D-CRLH D-CRLH TL used in the dual-band power divider.

The simulations indicate that the power divider will function with acceptable performance within the two OFDM/DS-UWB bands (1.0 to 4.8 GHz and 6.2 to 9.2 GHz). To evaluate actual circuitry, the D-CRLH power divider was fabricated with the layout of *Fig. 4*. The D-CRLH cell consists of an interdigital capacitor shunted with a strip inductor, followed by a series inductor with a patch capacitor.

The cell is based on low-loss printed-circuit-board (PCB) material from Rogers Corp. (www.rogers.com) with relative dielectric constant (ε_r)



6. The design process for the D-CRLH power divider included (a) the block diagram, (b) a 2D layout with L_f = 5 mm and W_f = 3.45 mm, and the prototype fabricated on commercial PCB material.

of 3.55 and thickness of 1.52 mm. The dimensions of the circuitry were extracted according to Eq. 7[29]:

$$L = (Z_c/\omega)\tan(\beta l_L),$$

$$C_I\ (\text{pF}) = 3.937 \times 10^{-5}\, l_I(\varepsilon_r + 1)[0.11(n - 3) + 0.252] \quad (7)$$

where L is the inductance of the stripline; l_L is the length of the strip inductor; z_c is the characteristic impedance of the strip inductor; C_I is the interdigital capacitance; l_I is the width of the interdigital capacitor; and n is the number of interdigital capacitor fingers. The capacitor finger length was chosen for a given finger spacing that could be practically fabricated.

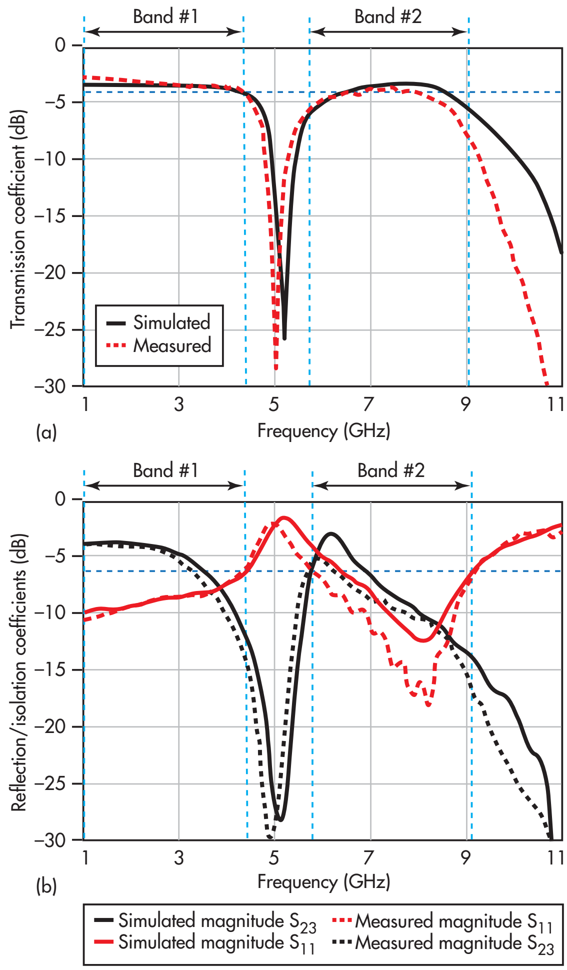
Based on the calculated dimensions of the strip inductor, some fine-tuning was performed. CST Microwave Studio (www.cst.com) three-dimensional (3D) electromagnetic (EM) simulation software was used to achieve the final circuit element dimensions listed in Table 1.

To confirm the behavior of the D-CRLH cell, simulated full-wave S-parameters were used to create the dispersion diagram of *Fig. 5*. It starts with RH behavior within the first passband extending from dc to 4 GHz. The stopband extends from 4.3 to 5.8 GHz. The second passband, with LH behavior, extends from 6.2 to 11 GHz.

Figure 6(a) shows a block diagram of the two-way power divider. It employs one cell of the dual-band impedance transformer in each branch of the divider. *Figure 6(b)* shows a layout for the dual-band D-CRLH power divider, which is designed to equally divide power applied between its input port and the two output ports. The miniature power divider measures just 21.4 × 16.6 mm^2 or $0.27 \times 0.22\lambda_g^2$, where wavelength λ_g is calculated at the midband frequency of the first passband. *Figure 6(c)* shows the prototype power divider fabricated on commercial PCB material.

S-parameter magnitudes of the D-CRLH power divider were measured with a commercial, two-port vector network analyzer (VNA). Figure *7(a)* provides a comparison between measured and full-wave simulated S_{21} results for the D-CRLH power divider, with reflection coefficient (S_{11}) and isolation coefficient (S_{23}) results in *Fig. 7(b)*.

These results show the two passbands from 1 to 4.8 GHz and 6.2 to 9 GHz with good agreement between measurements and simulations. The S_{21} magnitude is better than −4 dB throughout the two passbands. Better performance is achieved in the first passband, where S_{21} is about 3.3 dB across the full band.



7. The plots show full-wave simulated and measured results for the two-way power divider: (a) transmission coefficient (S_{21}) and (b) reflection (S_{11}) and isolation (S_{23}) coefficients.

TABLE 2: COMPARING THE EXPERIMENTAL POWER DIVIDERS WITH PREVIOUS WORK

Source	Bands	Size (mm^2)	Size (λ_g^2)	Frequency (GHz)	Insertion loss (dB)	Return loss (dB)
This work	2	16.6 × 20.4	0.22 × 0.27 0.72 × 0.88	1.0 to 4.7 6.2 to 9.0	3.3 ± 0.3	10
Ref. 23	2	22.5 × 25	0.19 × 0.22 0.67 × 0.76	1.0 to 2.78 6.25 to 7.1	3.0 ± 0.5	10
Ref. 24	1	12.9 × 43.48	0.4 × 1.37	3.1 to 10.6	3.0 ± 0.5	11
Ref. 25	1	22 × 16.33	0.29 × 0.22	1.8 to 2.45	3.0 ± 0.5	30
Ref. 26	2	24 × 24	0.27 × 0.35 0.39 × 0.5	3.5 to 5.0	3.0 ± 0.9	13-15

In the upper passband, the measured S_{21} drops from −4 dB at 8.4 GHz to −6 dB at 9 GHz. For S_{11}, the simulated and measured values are both below −6 dB for both passbands. Isolation differs for the two bands, with performance of about −4 dB for the lower passband and better than −6 dB for the higher passband.

Considering that the power divider is a modified T-junction, with best-case loss of about −6 dB, it provides reasonable isolation. The stopband, for rejection of WLAN signals, extends from 4.8 to 5.8 GHz, with S_{21} reaching −33 dB at 5 GHz. Within this stopband, the return loss reaches 2 dB at 5 GHz.

The design tradeoffs for this power divider include good return and insertion losses for the two passbands and high attenuation within the stopband, at the same time maintaining good isolation between the two output ports. These electrical characteristics were pursued while also attempting mechanical miniaturization of the power divider. The design offers competitive results with some of the latest power-divider designs *(Table 2)*, while being about 45.37% smaller than a conventional design. mw

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PROPER TESTING SAFEGUARDS THE PERFORMANCE OF NFC-ENABLED PRODUCTS

NEAR-FIELD COMMUNICATIONS (NFC) technology has gained considerable market traction. The technology is both easy to use and has the versatility to support a wide range of consumer and business applications. NFC subsystem performance can be affected by subtle variations that can occur during device production. Therefore, manufacturers must employ verification tests to ensure the proper functionality of NFC-enabled products. In the white paper, "*Test Considerations for NFC Enabled Devices in Manufacturing*," LitePoint discusses the importance of NFC testing, explaining how the accuracy and effectiveness of production tests can be ensured.

The white paper describes NFC technology, which is a short-range wireless technology that operates at 13.56 MHz. NFC enables two-way communication, as devices communicate with each other by means of magnetic field induction when in close proximity—typically 4 cm or less. NFC utilizes amplitude-shift-keying (ASK) modulation. Data rates range from 106 to 848 kbps.

NFC products have been shipping for several years. Although they were originally slow to gain traction, nearly 2 billion NFC-enabled devices are expected to ship in 2017. These products include smartphones, tablets, PC accessories, and gaming consoles. NFC technology has also generated interest because it offers the potential to enable mobile wallets and other financial transactions. In fact, ABI Research expects the value of NFC-enabled transactions to reach $191 billion in 2017.

LitePoint, 965 West Maude Ave, Sunnyvale, CA 94085; (866) 363-1911; www.litepoint.com

But NFC technology must allow for a successful user experience to sustain its momentum and continue its mainstream usage. Thus, it is crucial that manufacturers offer properly functioning NFC devices. Malfunctioning devices could result in a number of negative consequences—for example, payment disruptions that affect businesses.

The white paper presents a typical architecture of an NFC-enabled smartphone, explaining the key components that should be tested during manufacturing. Frequency response testing and basic connectivity testing, which are both recommended to be performed in the manufacturing environment, are explained in further detail. The document concludes by describing LitePoint's IQnfc+ tester, which supports measurements of the key NFC standards.

EASE PACKAGED PA THERMAL-MANAGEMENT CONCERNS

SYSTEM ENGINEERS CAN now take advantage of amplifiers based on gallium-nitride (GaN) technology to generate higher output power levels in smaller physical systems. However, these GaN devices also require sufficient thermal management. In the white paper, *"CW Operation of QFN-Packaged Pulsed GaN Power Amplifiers,"* Qorvo discusses thermal issues associated with using QFN-packaged GaN power amplifiers (PAs), originally designed for pulsed operation, in continuous-wave (CW) mode. Qorvo's TGA2307-SM GaN PA is used as an example.

The white paper explains that many high-power, packaged GaN devices that were originally intended to be used in pulsed applications are also being considered for high-power CW systems, owing to these devices' small size and weight. Proper thermal management of these GaN devices can be challenging due to several factors, such as the smaller package's thermal footprint. One example of such a device is the TGA2307-SM PA, which was originally developed to be used primarily for pulsed applications. This PA is housed in a 6-×-6-mm, 40-pin QFN package.

Qorvo Inc., 2300 NE Brookwood Pkwy., Hillsboro, OR 97124; (844) 890-8163; www.qorvo.com

Employing copper-filled thermal vias under the center pad of a package is one thermal-management technique. However, the white paper notes that this approach is not adequate for power levels exceeding the 10-to-15 W range. Printed-circuit-boards (PCBs) with openings for heat sinks with machined pedestals and coined PCBs are two solutions for higher-power dissipation applications. They allow for a much lower thermal resistance from the package through the PCB to the external heat sink.

To determine if the TGA2307-SM is well suited to be used in CW mode, three material stack-up environments are simulated. The first method utilizes 8-mil-filled thermal vias with the PCB epoxy-attached to a heat sink. The other two methods use a 20-mil coined PCB, which in both cases is also attached to a heat sink. However, two different approaches are taken for the PCB-to-heat-sink attachment, as one case uses epoxy, while the other uses solder. The results of all three thermal simulations are shown.

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MEMS OSCILLATORS Offer Precision Timing

These MEMS-based oscillators provide the dynamic performance with temperature and vibration to maintain outstanding frequency stability under real-world conditions.

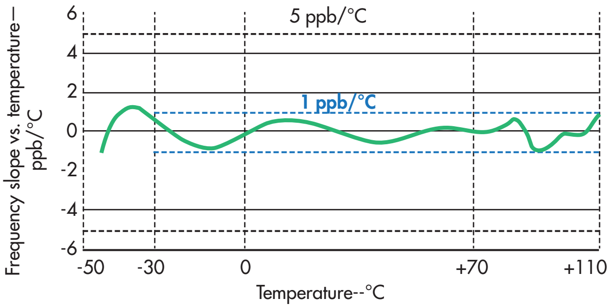
TIMING AND SYNCHRONIZATION of components and subsystems are necessary for many electronic systems, typically relying upon the stability of a reference oscillator. Until now, system timing in high-performance applications was typically based on a stabilized crystal oscillator, such as a temperature-compensated crystal oscillator (TCXO) or oven-controlled crystal oscillator (OCXO); however, miniature oscillators based on microelectromechanical-systems (MEMS) technology offer a new timing alternative with impressive stability for a wide range of timing requirements. In addition, the silicon MEMS-based oscillator families in the new Elite Platform product line from SiTime *(www.sitime.com)* push the performance of this technology to new levels , in the presence of changing environmental conditions, for any clock frequency from 1 to 220 MHz and as high as 700 MHz for differential outputs.

1. The Elite Platform of silicon MEMS-based clock oscillators reaches frequencies to 220 MHz in standard models and 700 MHz in differential models.

Quartz has been a building-block material for stable oscillators for some time, providing excellent frequency stability. The most demanding requirements, however, require that quartz oscillators are compensated or stabilized in some way because they are susceptible to rapid changes in temperature. One solution involves using an OCXO, although they tend to be relatively large (compared to an uncompensated crystal oscillator) and require considerable power consumption to maintain constant temperature within an oven-controlled package. OCXOs also employ fairly complex construction, which can compromise reliability. Quartz is also susceptible to the effects of environmental noise, such as vibration, and can suffer frequency variations in such environments.

Sufficient vibration at a wireless cellular base station or small cell employing a quartz-based clock oscillator can result in dropped calls and lost data for transmissions within that wireless network. In addition, quartz oscillators can suffer frequency instability with rapid changes in temperature and over a wide operating temperature range. The stability requirements of a particular communications network will dictate the type of time-keeping oscillator required for that system. As an example, IEEE1588 Grandmaster clocks, which are often specified for precision network synchronization applications, have a frequency-over-temperature-slope ($\Delta f/\Delta T$) requirement of 1 ppb/°C. Such a challenging requirement calls for an oscillator that is relatively immune to the effects of rapid temperature changes in the surrounding environment, such as an OCXO. A quartz-based OCXO oscillator provides outstanding frequency stability with rapid changes in temperature, although in a much larger package (because of the oven) than a standard quartz oscillator and with much greater power consumption than a standard quartz oscillator.

In contrast, the new MEMS oscillators from SiTime are based on silicon, not quartz *(Fig. 1)*. They offer the $\Delta f/\Delta T$ performance for an application like IEEE 1588 Grandmaster clocks (1 ppb/°C) in a fraction of the size of an OCXO and with much less power consumption. The basic architecture consists of a pair of the company's DualMEMS™ MEMS resonators—one for timing and the other for temperature sensing—connected to a mixed-signal silicon CMOS integrated circuit (IC) within a single package, such as an eight-lead SOIC-8 package. The CMOS IC includes the phase-lock-loop (PLL) circuitry needed for generated the required frequency and circuitry for maintaining high stability, such as on-chip temperature sensors, on-chip temperature compensation, and



2. Clock oscillators in the Elite Platform product line employ silicon MEMS and analog technologies to achieve OCXO-like frequency stabilities for frequencies from 1 to 220 MHz.

voltage regulation *(Fig. 2)*. The different MEMS-based clock oscillators achieve impressive frequency stability with rapid temperature, changes, temperature variations due to airflow of in-system fans, power-supply fluctuations, mechanical shock and vibration, and other dynamic conditions common to applications in the field.

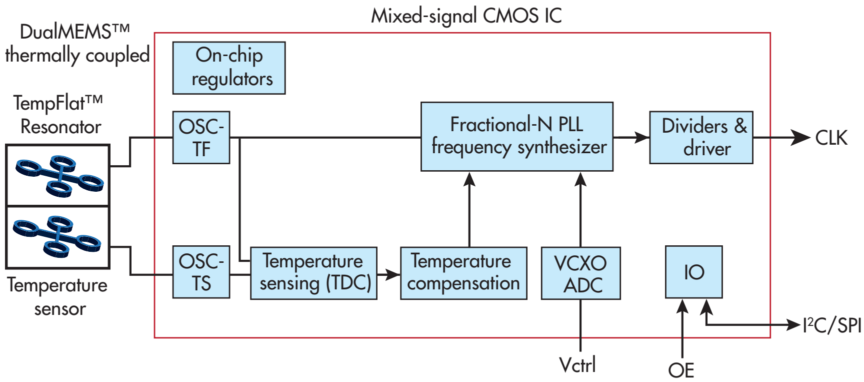
THE MEMS LINEUP

The new Elite Platform clock oscillators include MEMS VCXOs, differential MEMS oscillators (XOs), and Stratum-3-compliant Super-TCXOs. The differential MEMS oscillators and MEMS VCXOs are currently sampling while engineering samples of the Super-TCXOs will be available in the early part of 2017.

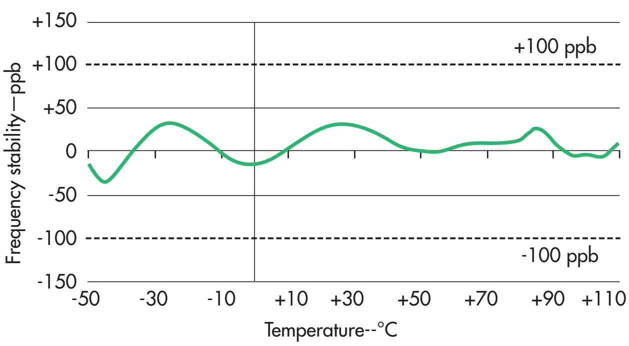
The differential MEMS oscillators are supplied in surface-mount QFN packages, measuring either 3.2 × 2.5 mm or 7.0 × 5.0 mm. Model SiT9365 oscillators are available for 32 standard frequencies, while model SiT9366 can be specified from 10 to 220 MHz and model SiT9367 from 220 to 700 MHz, both with frequency stabilities ranging from ±10 to ±50 ppm. The typical integrated RMS phase jitter (over 12 kHz to 20 MHz) is a mere 0.23 ps. These oscillators provide LVPECL, LVDS, and HCSL output formats. They are available for operating temperatures as wide as -40°C to +95°C. The differential MEMS VCXOs include model SiT3372, with frequencies from 10 to 220 MHz, and model SiT3373, with frequencies from 220 to 700 MHz. Both models are usable from -40°C to +95°C and supplied in QFN packages. Frequency stabilities range from ±10 to ±50 ppm with LVPECL, LVDS, and HCSL output formats.

The "standard" Super-TCXOs include model SiT5156, for frequencies from 1 to 60 MHz, and model SiT5157, for frequencies from 60 to 220 MHz, with both achieving frequency stabilities of ±0.5 ppm and ±0.5 to ±5 ppm, respectively. These clocks generate LVCMOS or clipped sinewave outputs. They are supplied in an SOIC-8 package measuring 6.0 × 4.9 mm. For even higher stability, the Precision Super-TCXOs include model SiT5356, with frequencies from 1 to 60 MHz, and model SiT5357, with frequencies from 60 to 220 MHz, and both devices also offer LVCMOS or clipped-sinewave output formats. These highly stable MEMS clock oscillators feature frequency stabilities of ±0.1 to ±0.25 ppm over temperature. Both Super-TCXO and Precision Super-TCXO families have operating temperature ranges as wide as -40°C to +105°C and are supplied in an SOIC-8 package.

In general, these MEMS-based clock oscillators offer excellent frequency stability over temperature *(Fig. 3)*. The frequency stabilities of the Super-TCXOs is easily in excess of the ±100 ppm frequency stability required for synchronization of communications networks and small cells in wireless systems. The MEMS oscillators are essentially immune to vibration, with



3. The innovative clock oscillators combine a pair of silicon MEMS resonators with CMOS circuitry that incorporates the power regulation, temperature sensing, and temperature compensation needed to maintain excellent frequency stability over temperature.



4. This plot shows almost unprecedented frequency stability of the Super-TCXO MEMS oscillators for temperatures from -50 to +110{DEG}C.

vibration sensitivity of 0.1 parts per billion per gravity (0.1 ppb/g). The oscillators exhibit an Allan deviation of 3 × 10^{-11} g, even better than the requirements of a Global Positioning System (GPS) clock. The oscillators also offer excellent airflow resistance, and are stable with dynamic changes in environmental conditions, such as rapid changes in temperature. The dynamic frequency stability is better than 5 ppb/°C for a 10°C/minute slope in temperature.

The Precision Super-TCXOs boast 0.2 ps/mV power supply noise rejection (PSNR), while the differential MEMS oscillators improve upon this to 0.02 ps/mV PSNR, eliminating the need for low-drop-out (LDO) linear regulators or expensive, dedicated power supplies *(Fig. 4)*. The various MEMS VCXOs provide 0.1% frequency tuning linearity under all conditions, with optional I^2C ports for frequency tuning, and replacing the need for an external digital-to-analog converter (DAC) for frequency tuning. The LVCMOS MEMS oscillators can be configured for optimum rise/fall times to achieve a desired jitter specification or for reduction of electromagnetic interference (EMI) in a particular application.

The trend in modern mobile communications systems, with the ever-growing number of wireless users and applications, is towards more compact, denser infrastructure equipment deployed in systems in less-controlled environments. These communications systems require small, low-power oscillators that provide high reliability and offer the dynamic performance needed for stable timing in uncontrolled environments. Even test equipment designers, as they look for smaller more modular footprints, will find needs for smaller, lower-power clock oscillators. For OCXO stability with a fraction of the size and power consumption, and with reliability that has been shown to be on the order of 1.5 failures per 1 million oscillators, these silicon MEMS oscillators represent a hard-to-beat solution. mw

SITIME, 5451 Patrick Henry Dr., Santa Clara, CA 95054; (408) 328-4400, www.sitime.com.

CHRIS DeMARTINO | Technical Editor

New Wideband EMC Absorbers Offer Solutions to 40 GHz

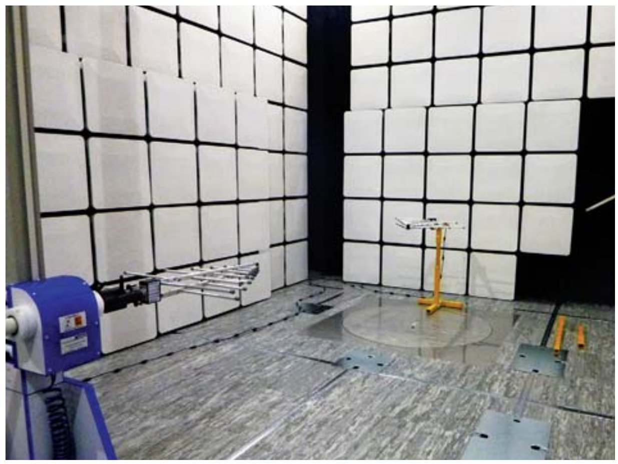
These polypropylene-based absorbers can be used in various test applications, covering frequencies ranging from 30 MHz to 40 GHz.

HIGH-QUALITY ABSORBERS ARE crucial when it comes to electromagnetic-compatibility (EMC) test applications. The Microwave Vision Group (MVG) is one company that is providing solutions to such applications, as demonstrated by its recent introduction of the ULTRA UH series of hybrid electromagnetic (EM) absorbers *(Fig. 1)*. The polypropylene-based absorbers can perform for up to 35 years without degradation, according to MVG. They are designed to meet the requirements of pre- and full-compliance EMC testing. The ULTRA UH absorbers can be used in EMC chambers as a hybrid combined with ferrite tiles, as well as mixed-use test facilities *(Fig. 2)*.

Polypropylene material offers several major benefits over previously used polystyrene and thin-film absorbers. For one, the material has a highly uniform carbon density, which can allow for more predictable results with no discontinuities. Carbon is never shed due to the closed cell material.

The absorbers are created by precise molding techniques, thereby ensuring that all products are identically shaped and sized. This feature allows for fast installation, as well as providing the chamber interior with a high-quality finish. MVG says the absorbers are very tough and resistant to wear. And because they do not absorb moisture, air conditioning is not essential.

1. These wideband absorbers cover a frequency range of 30 MHz to 40 GHz.



2. This is a CISPR-16-compliant 3m chamber lined with ULTRA UH series absorbers.

The absorbers cover a wide frequency range from 30 MHz to 40 GHz. The standard base size is 1.97 × 1.97 in. (60 × 60 cm). Moreover, RF power-handling capability is as high as 600 V/m. Furthermore, the ULTRA UH series of absorbers meets the GER-DIN 4102 Class B2 fire-retardancy standard.

MVG offers several design variations of the ULTRA UH series. Customers can choose between the UH30, UH50, and UH 75 absorbers, which have heights of 30, 50, and 75 cm, respectively. The company is also offering the UHC30, which is a high-carbon absorber that has a specifically enhanced reflectivity to meet emission testing (1 to 18 GHz) site-voltage-standing-wave-ratio (sVSWR) requirements when used as a floor absorber.

In terms of weight, the UH30, UH50, and UH75 weigh 1.9, 4.1, and 5.3 kg, respectively. The UH30 is designed with 36 pyramid points, while the UH50 and UH75 are designed with 16 and nine, respectively. In regard to absorption characteristics, the UH30's absorption at normal incidence is 37.2 dB at 18 GHz. Meanwhile, absorption at normal incidence of the UH50 and UH75 are 49.3 dB and 51.2 dB, respectively, at 18 GHz. mw

THE MICROWAVE VISION GROUP; www.mvg-world.com

JACK BROWNE | Technical Contributor

Pocket-Sized Power Analyzer Extends to 70 GHz

This compact tester works with a PC or other computing device to perform frequency-selective power measurements from 9 kHz to 70 GHz—whether in the lab or in the field.

SIGNAL POWER TENDS to fade at higher frequencies, due to the scarcity of power at those frequencies in addition to propagation and transmission losses. But it still must be measured, especially as more applications trend toward higher frequencies to accommodate the growing number of wireless users and applications.

To address this need, Anritsu Co. *(www.anritsu.com)* developed the Power Master MA24507A power analyzer *(see figure)*, which performs frequency-based measurements of power over a frequency range from 9 kHz to 70 GHz, and over as many as six frequency channels at one time for channel power monitoring.

It is designed to connect via USB to a PC running Power Xpert test software. It features a wide dynamic range, detecting signal power levels as low as –100 dBm and as high as +10 dBm at most frequencies (and as low as –90 dBm at 70 GHz).

Like a spectrum analyzer, operators are able to set a channel bandwidth around a center frequency of interest, the better to monitor power levels of known signals. With the PowerXpert software and its Channel Monitor mode, users can set as many as six frequency channels to monitor continuous-wave (CW) amplitude or channel power simultaneously.

The test software also provides a Power Hunter mode that detects the six highest signal CW amplitudes and their frequencies across a frequency range of interest. In this measurement mode, the instrument can be set to look for signals with power levels from –90 to +10 dBm for start frequencies from 9 kHz to 70 MHz at spans of 1 kHz to 20 MHz.

This compact power analyzer, which connects to a computer through the USB port, delivers precise power measurements on as many as six channels from 9 kHz to 70 GHz.

IDEAL FOR THE FIELD

The powerful analyzer fits in a package measuring just 6 × 3 × 1 in. and weighs less than 15 oz. It thus becomes a viable candidate, along with a battery-powered laptop computer, for over-the-air and in-the-field on-site testing such as channel monitoring or interference detection. The instrument includes a 1.85-mm coaxial (V) connector to cover the wide frequency range and maintains excellent frequency accuracy by means of an internal reference oscillator with stability of ±0.1 ppm. Unlike traditional benchtop power meters, no reference calibration is required; the instrument can remain active for continuous on-air measurements while maintaining full accuracy.

The Power Master MA24507A delivers typical amplitude accuracy of ±1.0 dB throughout its power measurement range, at temperatures from 0 to +50°C. It achieves relative power accuracy of ±0.3 dB across the full frequency range of 9 kHz to 70 GHz.

When speed is important, such as in production test applications, the MA24507A performs multiple measurements per second. By way of example: For channel power measurements at a 1-GHz center frequency and span of 20 MHz, the measurement speed is clocked at 20 measurements/s and 25 measurements/s for a CW signal.

This pocket-sized analyzer makes it possible to get close to a signal source, or to find the most distant signal sources at extremely low detectable levels. With its multiple-channel measurement capability, it can perform adjacent-channel-power (ACP) measurements as well as channel monitoring over wide frequency spans. The PowerXpert software runs on computers with Microsoft Windows 7, 8.1, and 10 operating-system (OS) software. mw

ANRITSU CO., 1155 East Collins Blvd., Ste. 100, Richardson, TX 75081; (800) 267-4878, (972) 644-1777, www.anritsu.com

JACK BROWNE | Technical Contributor

Distributed Amplifiers Command DC to 22 GHz

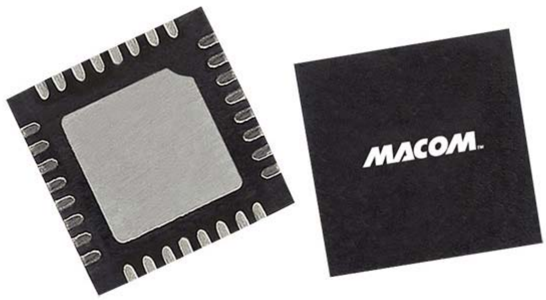
This rugged, versatile SP4T switch matrix boasts outstanding electrical performance and ease of use

BROADBAND FREQUENCY COVERAGE in an amplifier means that one amplifier can serve many purposes, even for applications requiring coverage of a continuous frequency range, such as in test equipment. The models MAAP-011247 and MAAP-011248 GaAs pHEMT amplifiers from MACOM Technology Solutions are two such components, distributed power amplifiers with broad frequency range of DC to 22 GHz, with the kind of bandwidth where one amplifier can nearly do it all.

As reported recently at the 2016 EDICON US exhibition, these two distributed amplifiers are not only broadband enough to cover a host of different applications, they can also function as either driver amplifiers or power amplifiers in low-power applications. Both amplifiers are matched to 50 Ω across their 22-GHz bandwidths and both maintain consistent performance at all frequencies. For example, in spite of the extremely wide bandwidth, the model MAAP-011247 amplifier provides flat gain with little deviation: typically 12.0 dB at 2 GHz, 11.5 dB at 12 GHz, 12.0 dB at 18 GHz, and 11.5 dB at 22 GHz. Likewise, the output power at 1-dB compression is nominally +30 dBm (1 W), hitting +30 dBm at 2 GHz, +31 dBm at 12 GHz, +30 dBm at 18 GHz, and +28 dBm at 22 GHz.

The saturated output power is also flat with frequency, reaching +32.0 dBm at 2 GHz, +33.5 dBm at 12 GHz, +33.0 dBm at 18 GHz, and +31.0 dBm at 22 GHz. The output third-order intercept point (output IP3) is +42 dBm at 2 GHz, +46 dBm at 12 GHz, +42 dBm at 18 GHz, and +44 dBm at 22 GHz. The wideband amplifier achieves reasonable power-added efficiency (PAE) of 16.5% at 2 GHz, 20.0% at 12 GHz, and 17.0% at 18 GHz, tailing off a bit at the highest frequencies, reaching 12.0% at 22 GHz. The amplifier is available in die form or in an RoHS-compliant 32-lead AQFN package *(see figure)* measuring 5 × 5 mm. The broadband amplifier typically draws 500 mA from a +15 V dc supply.

When slightly less output power is needed (with correspondingly less power consumption), model MAAP-011248 also covers the frequency range from dc to 22 GHz but with typically +30 dBm (1 W) output power at 1-dB compression. Its output power remains within a 3-dB window, with output power at 1-dB compression of +28 dBm at 2 GHz, +30 dBm at 12 GHz, +27 dBm at 18 GHz, and +27 dBm at 22 GHz. The gain is quite flat with frequency, with gain of 12.0 dB at 2 GHz, 12.5 dB at 12 GHz, 13.0 dB at 18 GHz, and 13.0 dB at 22 GHz. The saturated output power is fairly level with frequency, with +31 dBm at 2 GHz, +33 dBm at 12 GHz, +32 dBm at 18 GHz, and +30 dBm at 22 GHz. The PAE for the MAAP-011248 is 17% at 2 GHz, peaking at 25% at 12 GHz, and back to 17% at 18 GHz, and falling to 13.5% at 22 GHz. These PAE values are based on a bias supply of +12 V dc and 400 mA current. The amplifier can also operate on +10 V dc and 400 mA but with slightly less PAE.



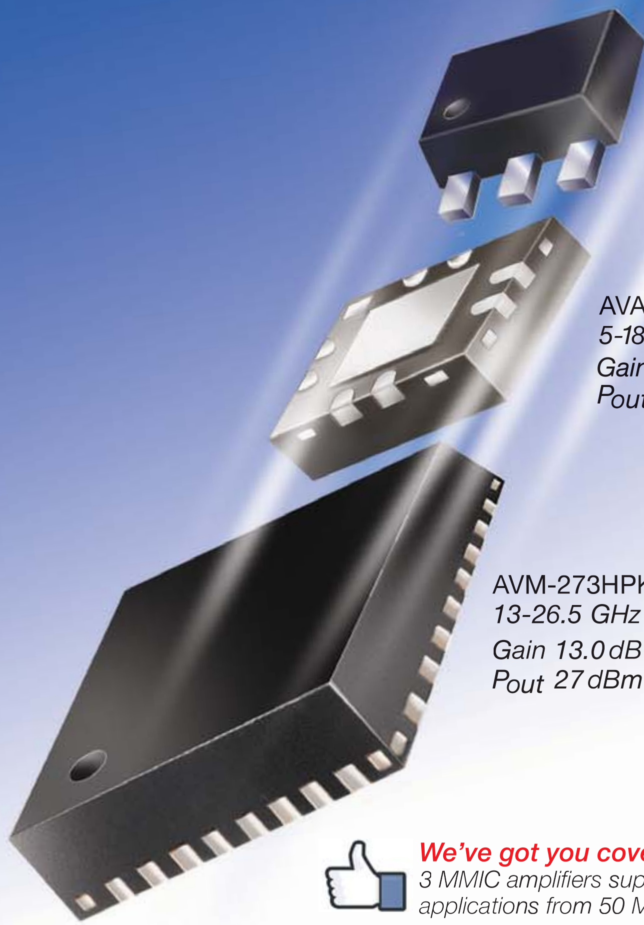
Models MAAP-011247 and MAAP-011248 are 2- and 1-W distributed amplifiers that operate from DC to 22 GHz. They are available in chip form and, as shown, in 32-lead AQFN packages.

These broadband amplifiers can meet many requirements with low-voltage supplies and fairly efficient operation. The amplifiers are well matched, with input and output return loss of typically 15 dB when measured with +20-dBm input power. Both amplifiers are designed integral temperature-compensated output-power detector to maintain level output power across a broad operating temperature range of -40°C to +85°C. mw

MACOM TECHNOLOGY SOLUTIONS, 100 Chelmsford St., Lowell, MA 01851; (978) 656-2500, www.macom.com

MMIC AMPLIFIERS

50 MHz to 26.5 GHz



We've got you covered!
3 MMIC amplifiers support the whole gamut of applications from 50 MHz all the way up to 26.5 GHz!

Mini-Circuits' AVM-273HPK+ wideband microwave MMIC amplifier supports applications from 13 to 26.5 GHz with up to 0.5W output power, 13 dB gain, ±1 dB gain flatness and 58 dB reverse isolation. The amplifier comes supplied with a voltage sequencing and DC control module providing reverse voltage protection in one tiny package to simplify your circuit design. This model is an ideal buffer amplifier for P2P radios, military EW and radar, DBS, VSAT and more!

The AVA-183A+ delivers 14 dB gain with excellent gain flatness (±1.0 dB) from 5 to 18 GHz, 38 dB isolation, and 19 dBm power handling. It is unconditionally stable and an ideal LO driver amplifier. Internal DC blocks, bias tee, and microwave coupling capacitor simplify external circuits, minimizing your design time.

The PHA-1+ uses E-PHEMT technology to offer ultra-high dynamic range, low noise, and excellent IP3 performance, making it ideal for LTE, and TD-SCDMA. Good input and output return loss across almost 7 octaves extend its use to CATV, wireless LANs, and base station infrastructure.

Visit minicircuits.com for full specs, performance curves, and free data! These models are in stock and ready to ship today!

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JACK BROWNE | Technical Contributor

Color Touchscreen Tunes Ka-Band TWTA

This rack-mountable, 700-W pulsed power amplifier includes a modern touchscreen interface for local control of signals from 34.5 to 35.5 GHz.

TRAVELING-WAVE-TUBE AMPLIFIERS (TWTAS) are physically large, but still unmatched in terms of high output power at microwave frequencies. While acknowledged as a mature active-device technology, the model dB-3860-01 Ka-band TWTA from dB Control *(www.dBControl.com)* adds a bit of "modernization" with microprocessor-based control circuitry and a front-panel color-touchscreen interface to simplify operator control. The rugged high-power amplifier provides minimum pulsed output power of 700 W from 34.5 to 35.5 GHz with at least 60-dB gain across the 1-GHz output bandwidth.

The model dB-3860-01 Ka-band TWTA *(Fig. 1)* is well-equipped to handle applications in radar, electronic-warfare (EW) simulators, and test-and-measurement systems. Based on a wideband periodic-permanent-magnet (PPM)-focused, conduction-cooled TWT, it is designed to amplify pulsed signals at pulse widths from 0.2 to 20.0 μs and duty cycles to 10% at maximum pulse repetition frequencies (PRFs) to 25 kHz. It features excellent spectral purity, with harmonic performance of –30 dBc or better and spurious levels of –50 dBc or better.

The color-touchscreen interface works with an embedded microprocessor to provide straightforward local control of the Ka-band TWTA as well as coordinate protection functions and provide status reports and indication. TWTA protection includes overtemperature, helix overcurrent, and cathode overvoltage protection.

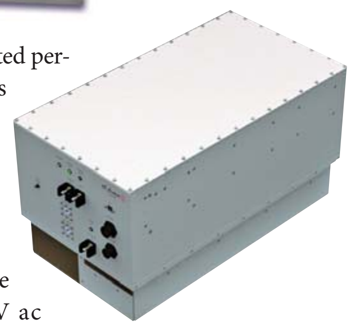
When remote control is preferred, as in an automatic-test-equipment (ATE) application, the model dB-3860-01 TWTA is equipped with an RS-485 interface. However, other digital-control interfaces, such as Ethernet, RS-232, and RS-422 interfaces, as well as custom interfaces, are available.

BUILT TOUGH

The rugged TWTA comes in a standard 19-in. rack-mount configuration with integral forced-air cooling system. It is equipped with WR-28 waveguide input and output connectors and a female Type K coaxial output connector for sampling and measurement purposes. The amplifier is built to withstand unfavorable impedance-match conditions, rated for a maximum input VSWR of 2.0:1 across the operating frequency range. The amplifier is geared to meet its rated performance specifications in terms of power and gain for a maximum load VSWR of 1.30:1, and can withstand load mismatches as high as 2.0:1 without damage.

1. Model dB-3860-01 is a pulsed Ka-band TWTA with color-touchscreen local-control interface.

The pulsed Ka-band power amplifier is designed for use with three-phase, 115/200-V ac prime power. It weighs 100 lb. and measures 24.5 × 19.0 × 7.0 in. The amplifier is built for operating temperatures from –20°C to +55°C and can operate at altitudes to 10,000 ft.



2. Model dB-3709i is an outdoor hub-mount pulsed TWTA capable of delivering 700-W output power from 34.5 to 35.5 GHz.

For those who prefer this level of pulsed amplification in a hub-mount, outdoor package, the firm also offers its model dB-3709i Ka-band TWTA with 700-W minimum peak output power from 34.5 to 35.5 GHz *(Fig. 2)*. It's built around a PPM-focused, conduction-cooled TWT and handles similar pulse types and duty cycles while delivering at least 60-dB gain across the 1-GHz bandwidth. For remote control, it also provides a standard RS-485 interface and is available with Ethernet, RS-232, RS-422, and custom control interfaces.

The model dB-3709i, which measures 26 × 14 × 14 in. and weighs 110 lb., features WR-28 input and output waveguide flanges and a type K output sample connector. It is rated for operating temperatures from –30°C to +55°C and operating altitudes to 15,000 ft. mw

DB CONTROL, a Heico Co., 1120 Auburn St., Fremont, CA 94538; (510) 658-2325, www.dBControl.com

JACK BROWNE | Technical Contributor

Signal Analyzer Extends to 110 GHz

This powerful yet simple-to-use wideband signal analyzer provides the features and functions needed to bring millimeter-wave measurements to the masses.

MILLIMETER-WAVE FREQUENCIES are now in play for applications well beyond traditional military and scientific purposes, moving steadily into commercial communications and automotive radar. The expected big push for millimeter-wave applications will involve backhaul connections in Fifth Fifth-Generation (5G) cellular communications systems.

To make it all possible, flexible and capable test equipment will be needed—and that equipment may have just arrived in the form of the N9014B UXA X-Series signal analyzer from Keysight Technologies *(www.keysight.com)*. It boasts an amazing frequency range of 3 Hz to 110 GHz and analysis bandwidths to 5 GHz, for measurements on audio electronics and millimeter-wave circuits and components, as well as everything in between.

The N9014B UXA *(Fig. 1)* is the flagship of the company's X-Series signal-analyzer line. Different versions provide continuous sweeps from 3 Hz to 90 GHz or 3 Hz to 110 GHz *(Fig. 2)*, depending on the choice of options, using a 1-mm coaxial test port input connector. Internal instantaneous analysis bandwidth is as wide as 1 GHz, and can be extended to 5 GHz by connecting the analyzer's intermediate-frequency (IF) output to a suitable digital sampling oscilloscope (DSO) from Keysight. The UXA benefits from the company's advanced front-end circuitry and high-frequency indium phosphide (InP) semiconductor technology.

TAKING ON TODAY'S WIDE BANDWIDTHS

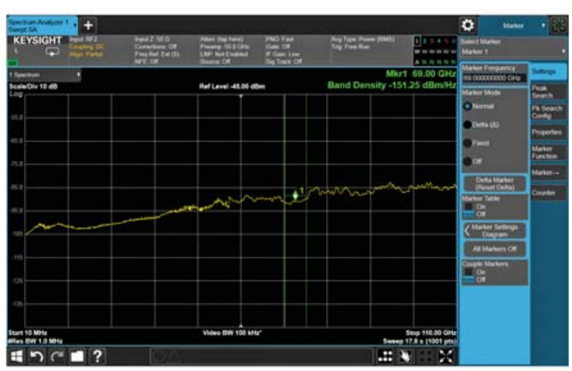
To handle signal analysis of the wide bandwidths required for modern modulation formats, the UXA comes with internal analysis bandwidths of 25, 40, 255, and 1000 MHz, depending on option. These bandwidths achieve spurious-free dynamic ranges (SFDRs) of –100, –80, –78, and –56 dBc, respectively.

The instrument's amplitude flatness is ±1.8 dB from 50 to 75 GHz and ±2.0 dB from 75 to 110 GHz, with absolute amplitude accuracy of 0.12 dB at a reference frequency of 50 GHz. It is designed for studying the low-level signals that typify millimeter-wave frequencies, but includes input attenuation to safely handle input power levels just above 0.25 W.

The maximum safe input power level with 20-dB input attenuation is +25 dBm, while the maximum safe input power level with 0-dB input attenuation is +5 dBm. The analyzer achieves a 1-dB compression (P1dB) point of +20 dBm with 20-dB input

1. The N9014B UXA X-Series signal analyzer packs a great deal of measurement power into a rack-mount case with large, multi-touch screen, pushbuttons, and remote-control capability for flexibility and ease of use.

2. This screenshot shows the extremely wide span (10 MHz to 110 GHz in this case) that is possible with the N9014B UXA.



3. The wideband signal analyzer features impressive DANL, even for frequencies above 50 GHz.

attenuation of a single continuous-wave (CW) test tone and +5 dBm with 0-dB input attenuation of a single CW tone.

Input preamplification can extend to 50 GHz. The analyzer also achieves a displayed average noise level (DANL) of –150 dBm/Hz at frequencies higher than 50 GHz with 0-dB input attenuation and without preamplification. From the P1dB point to the DANL, the dynamic range extends as wide as 150 dB *(Fig. 3)*.

FLEXIBILITY

The N9014B UXA actually provides a pair of different front-panel male input connectors. A rugged, 2.4-mm coaxial connector is used for measurements from 3 Hz to 50 GHz. Due to the smaller dimensions required for smaller wavelengths at millimeter-wave frequencies, a 1-mm coaxial connector is employed for continuous frequency coverage from 3 Hz to 110 GHz, although it lacks the durability of the 2.4-mm connector and coupling and decoupling must be performed with care.

A programmable IF output with variable center frequency is included for use with an external oscilloscope. This enables analysis of bandwidths beyond the UXB's internal 1-GHz bandwidth limit.

For clarity of analysis and ease of use, the millimeter-wave signal analyzer features a 14.1-in. (357-mm) diagonal multi-touch display screen with 1280- × 800-pixel resolution. Front-panel pushbuttons provide straightforward control, as does a remote connection via Ethernet local-area network (LAN).

The analyzer can also be programmed via the firm's many test software tools running on a PC connected to the instrument. The internal software applications include tools for performing phase-noise, pulse, and noise-figure measurements, as well as for analyzing signals with several of the candidate advanced modulation formats for 5G wireless-communications systems. These include the Long-Term Evolution (LTE) frequency-division-duplex (FDD) and orthogonal-frequency-division-multiplex (OFDM) formats.

Millimeter-wave devices and components have long represented a somewhat esoteric corner of this industry, with their minute dimensions and small wavelengths, not to mention the difficulty of generating test signals and analyzing a device under test (DUT) at millimeter-wave frequencies. With the N9014B UXA X-Series signal analyzer, however, the task of evaluating a DUT at those high frequencies just got much easier. mw

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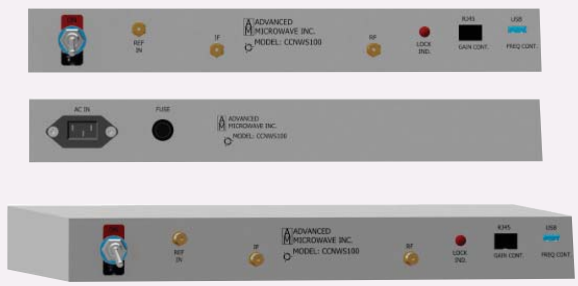
PS Form 3526-R, July 2014

GaN Amplifier Pushes 8 kW from 9.0 to 9.9 GHz

MODEL BMPC9X89X8-8000 is a solid-state power amplifier based on gallium nitride (GaN) transistor technology that is capable of 9 kW peak output power from 9.0 to 9.9 GHz. It handles input signals with pulse widths from 0.25 to 100 µs at 10% maximum duty cycle and provides 69-dB nominal gain. The unit suffers less than 1-dB pulse droop and achieves better than 50 ns typical rise/fall time. It works with instantaneous bandwidths to 500 MHz and provides the performance needed for X-band radar systems. Typical harmonics are –60 dBc, while typical phase noise is –100 dBc/Hz offset 100 Hz from the carrier. The rugged, rack-mount amplifier includes an Ethernet control interface. It is equipped with female SMA input and sample port connectors and WR-112 or WR-90 waveguide output ports. It measures 19.00 × 12.25 × 24.00 in. and weighs 90 lb.

COMTECH PST, 105 Baylis Rd., Melville, NY 11747; (631) 777-8900, e-mail: sales@comtechpst.com, *www.comtechpst.com*

Frequency Converters Extend from 3 to 40 GHz



THE CCNWS100 SERIES of frequency upconverters/downconverters operates in frequency bands covering a total RF range of 3 to 40 GHz and intermediate-frequency (IF) bands at L-, S-, or C-band frequencies in bandwidths of 2% to 8%. The passband ripple is controlled within ±0.2 dB across a 120-MHz bandwidth. The frequency converters feature gain of 30 to 50 dB, depending upon frequency range. Remote control of gain and frequency tuning are possible by means of local area network (LAN). Frequency tuning resolution is a fine as 1 kHz, and gain can be controlled in steps as small as 0.5 dB (6-b gain control).

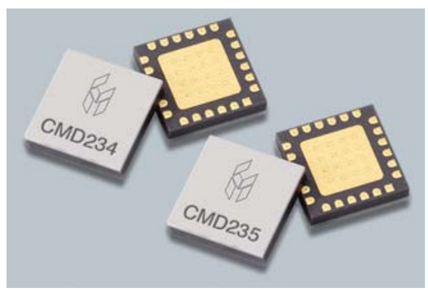
ADVANCED MICROWAVE, INC., 333 Moffett Park Dr., Sunnyvale, CA 94089; (408) 739-4214, e-mail: sales@advmic.com, *www.advmic.com*

Frequency Multiplier Produces 75 to 110 GHz

MODEL SFP-1022F-S1 is a W-band frequency doubler based on GaAs Schottky beam-lead diodes. It employs a balanced circuit configuration to generate second-order harmonics while effectively suppressing the amplitudes of the fundamental-frequency input signals. The frequency multiplier works with input signals from 37.5 to 55.0 GHz at +16 dBm and produces output signals from 75 to 110 GHz at +3 dBm. The multiplier is equipped with a 2.4-mm female coaxial input connector and a WR-10 waveguide output with UG-387/U-M flange.

SAGE MILLIMETER, INC., 3043 Kashiwa St., Torrance, CA 90505; (424) 757-0168, *www.sagemillimeter.com*

Multithrow Switches Control DC to 18 GHz



A PAIR OF non-reflective GaAs monolithic-microwave-integrated-circuit (MMIC) multithrow switches cover a wide frequency range of DC to 18 GHz. Model CMD234C4 is a single-pole, three-throw (SP3T) switch, while model CMD235C4 is a single-pole, five-throw (SP5T) switch. The former offers low insertion loss of 2.4 dB with high isolation of 40 dB at 10 GHz. The latter exhibits insertion loss of 2.5 dB with 40-dB isolation at 10 GHz. The switches offer 1-dB input-power compression at +21 dBm and achieve switching speed of 66 ns. Suitable for military and instrumentation applications, the switches feature binary decoder circuitry. Each switch is supplied in a RoHS-compliant surface-mount-technology (SMT) switch measuring 4 × 4 mm. They run on control voltages of 0 and –5 V dc.

CUSTOM MMIC, 300 Apollo Dr., Chelmsford, MA 01824; (978) 467-4290; *www.custommmic.com*

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