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Satellites will play a critical role in emerging communications applications p40

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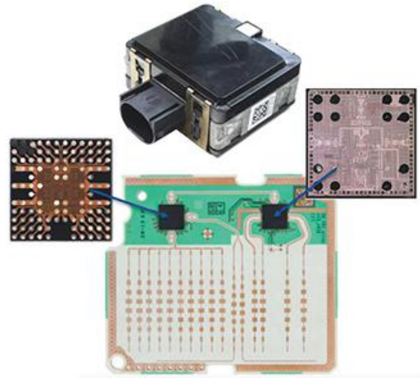

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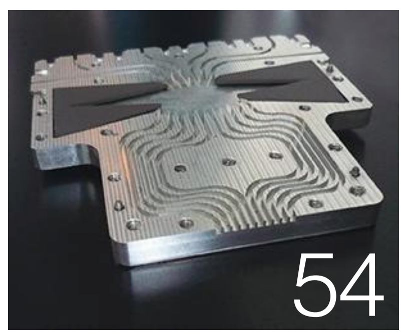

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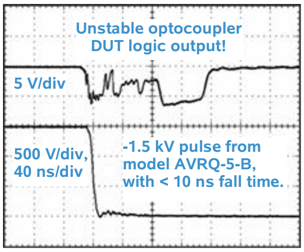
The Avtech AVRQ series of high-voltage, high-speed pulse generators is ideal for testing the common-mode transient immunity (CMTI) of next-generation optocouplers, isolated gate drivers, and other semiconductors.



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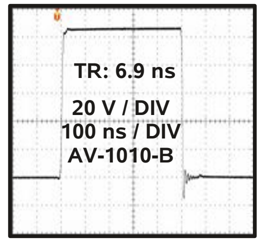

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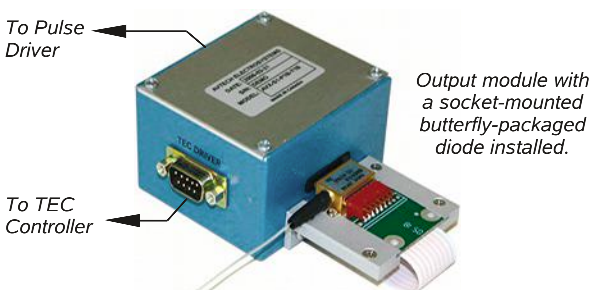
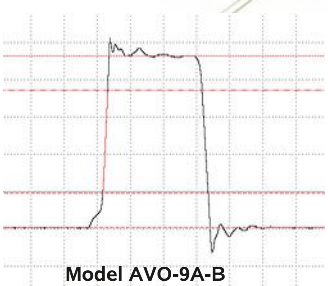
Nanosecond Laser Diode Drivers With Butterfly Diode Sockets





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1 ns/DIV

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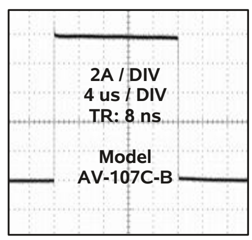

Series	I, V	PW	TR
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AV-106	5 - 100 A, 100 V	0.5 us - 1 ms	50 ns - 1 us
AV-108	12.5 - 200 A, 100V	2 us - 1 ms	5 - 15 us
AV-109	10 - 100 A, 5 V	10 us - 1 s	10 us
AV-156	2 - 30 A, 30 V	1 us -100 ms	0.2 - 50 us

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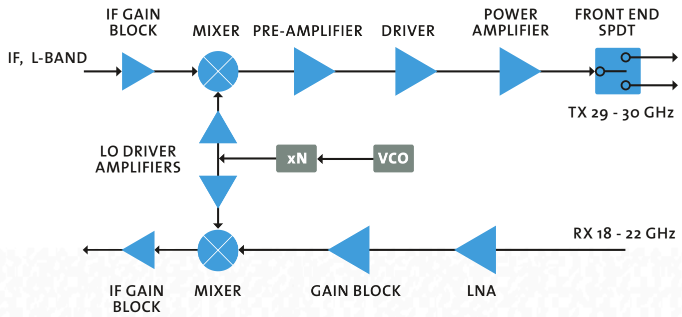

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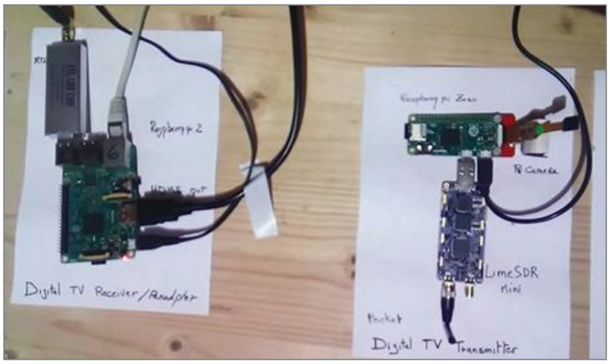

Q&A: Raspberry Pi Transmitter Targets Future Engineers

Developers have combined Raspberry Pi Zero and the LimeSDR Mini to create what they say is the world's smallest digital TV transmitter. To learn more, *Microwaves & RF* recently sat down with Lime's CEO, Ebrahim Bushehri.

http://www.mwrf.com/systems/qa-raspberry-pi-transmitter-targets-future-engineers

RF/Microwave Technology Helping Power EVs and HEVs

Electricity may one day rule the world's vehicles rather than gasoline. As fossil fuels become more expensive, and the technologies and manufacturing costs associated with electric vehicles (EVs) and hybrid electric vehicles (HEVs) become more affordable, the prices for EVs and HEVs will drop, making such vehicles more widespread on the roads.

http://www.mwrf.com/systems/rfmicrowave-technology-helping-power-evs-and-hevs

Turn to USB-Based Spectrum Analyzers to Conquer Interference

DECT stands for Digital Enhanced Cordless Technology, although some might suggest that the "E" actually stands for European. And, in fact, the DECT standard for cordless telephone systems did originate in Europe. Due in part to this development path, there are slight differences in the frequency ranges for European DECT phones and their North American counterparts. But these differences are significant if you are an information and communications technology (ICT) provider like SaskTel.

http://www.mwrf.com/test-measurement/turn-usb-based-spectrum-analyzers-conquer-interference

Oscilloscope Trigger Techniques for the RF Engineer

Modern real-time oscilloscopes are so powerful and feature-rich that for many engineers, the *AutoScale* button is all they ever need to learn. However, this is not usually the case for RF engineers. Bursty RF signals can be difficult to work with in the time domain, due in no small part to the difficulty many engineers have dialing in a stable trigger.

http://www.mwrf.com/test-measurement/oscilloscope-trigger-techniques-rf-engineer

Editorial

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

How Much (Or Little) Do You Currently Like Your Job, and Why?

The results from our salary survey indicate that most in the RF/microwave industry are satisfied with their current positions. Is that the case for you?

Here is a very simple question for those in the RF/microwave industry: Do you actually like your job today? And do you enjoy working for your company? Of course, there is no such thing as a perfect job, just like there is no such thing as a perfect company. Having said that, hopefully the engineering profession has been (and still is) good to you, meaning the answer to both of those previous questions is yes.

When thinking about your working experience, maybe another question would be this: Would you recommend engineering to your kids? Answering that question would go a long way toward crystallizing how one really feels about his or her job. The simple fact is that much of our time is spent at work. So with that in mind, it is definitely a huge benefit to do something that you actually enjoy. Unfortunately, that is not necessarily the case for many. Most likely you know more than a few people who really don't like their jobs.

So do engineers like their jobs? Based on the results we saw in last year's salary survey, it does appear that most engineers actually do. Of course, the salary survey is only a small sample of the engineering workforce. You have to answer yourself whether or not you feel the same as the majority of the survey respondents.

In addition, do you think that your company allows you to maximize your ability? Or do you feel like limitations are placed on you that actually prevent you from doing all that you can or want to do? You can have a whole lot of brainpower, but it doesn't necessary help if you don't use it. In situations in which an employee is being underutilized, is that the fault of the company or manager for not recognizing that person's abilities? Or is it somehow the fault of that person? That's another question to think about.

One last point is that the RF/microwave industry itself has clearly changed with all the mergers and acquisitions. It would be interesting to hear how that has affected your job — for better, worse, or not at all? Is your workload the same it was 5 or 10 years ago? Or has it significantly increased? We welcome any of your thoughts. mw

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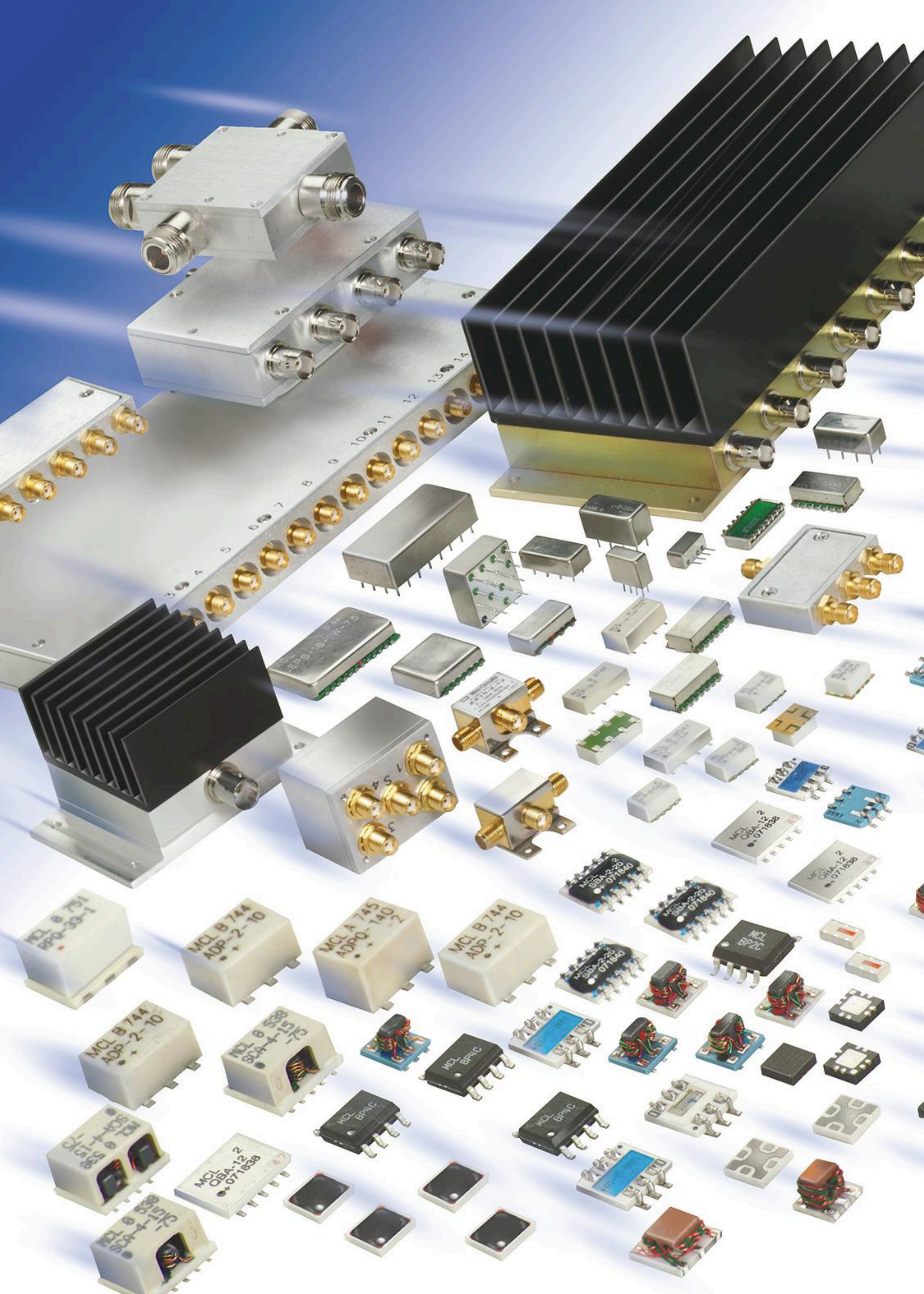
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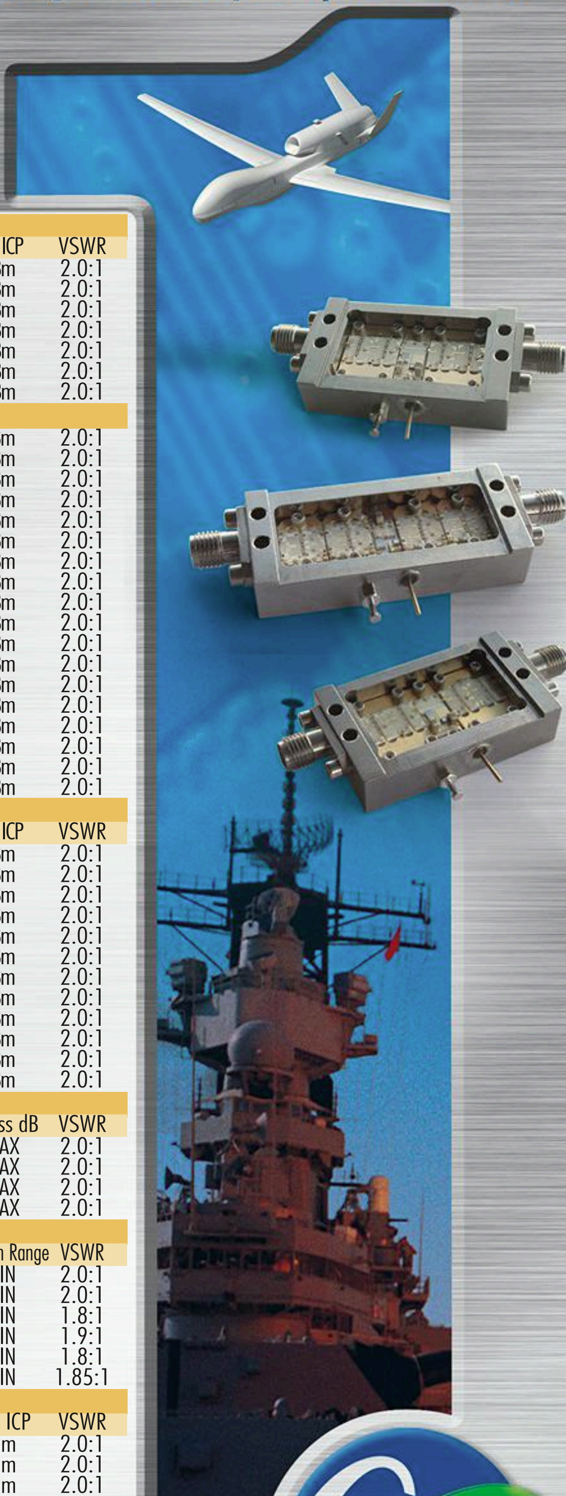

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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News

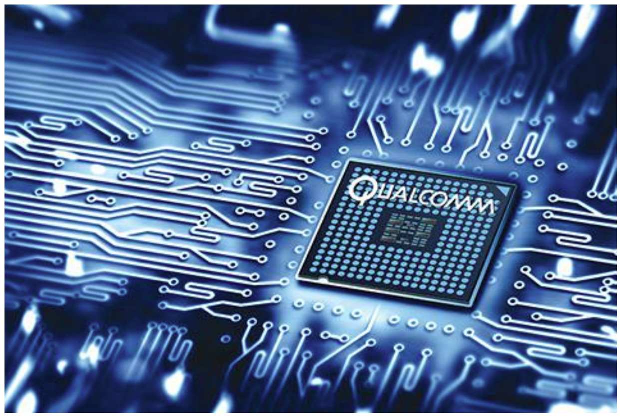
Qualcomm Runs Aground

on Its Third Continent in Three Years

The European Union slapped Qualcomm with a $1.23 billion fine for paying Apple to exclusively use its wireless modem chips in tablets and smartphones over a span of five years. The deal hurt competition in chips that connect devices to 3G and 4G networks, regulators said.

Following the fine, Qualcomm appealed to the general court of the European Union. The company, the world's largest supplier of LTE baseband chips, is now fighting regulatory battles across three continents. It has been increasingly under the microscope for the way it goes about negotiating deals with companies buying its chips and licensing the underlying patents.

The penalty is one of the worst black eyes that the company has suffered from regulators in the last three years. The company is fighting regulators in the U.S. for abusing its monopoly status over chips and it has been slammed with fines over the last three years totaling around $3.8 billion, which review in reverse order below.



VESTAGER IMPOSES HEFTY FINE WHILE ANOTHER INVESTIGATION LOOMS

The argument from European regulators is that Qualcomm shelled out billions of dollars of rebates as part of its contract with Apple, which agreed in exchange to use its wireless modems exclusively. The contract lasted from 2011 to 2016. Since it expired, Apple has started to source chips from Intel as well.

"These payments were not just reductions in price—they were made on the condition that Apple would exclusively use Qualcomm's baseband chipsets in all its iPhones and iPads," Margarethe Vestager, the E.U. competition commissioner, said in a statement. "This meant that no one could challenge Qualcomm effectively in the market for LTE baseband chipsets."

"This shows that Qualcomm's payments were decisive to shut out rival chip manufacturers from the market. Qualcomm's behavior denied rivals the chance to compete effectively, no matter how good their products were. And that denied consumers and other companies the benefits of choice and innovation."

Qualcomm said that the decision is not related to its patent licensing business, which has been the focus of other regulatory probes around the world. Apple has also fired several lawsuits over the licensing fees charged by Qualcomm, which subsequently accused Apple of demanding the rebates and collaborating with regulators to slash the billions it pays in chips and licensing fees.

Vestager and the European Commission are running a separate inquiry into allegations that Qualcomm severely discounted its chips to crush rivals in the market for modem chips — ones that could not survive being undercut on price. In response, Qualcomm sued the commission for harassment last year.

Qualcomm said that it strongly opposed the European Commission's decision. "We are confident this agreement did not violate E.U. competition rules or adversely affect market competition or European consumers," said Don Rosenberg, the company's vice president and general counsel, in a statement.

TAIWAN PENALIZES QUALCOMM FOR SEVEN YEARS OF LOCAL VIOLATIONS

In October 2017, Qualcomm incurred another fine in Taiwan said it had violated local laws by not supplying chips to clients who refuse to sign licensing deals or disagree with other conditions. Following a two year investigation, the fine came out to NT$23.4 billion or around $773 million.

Taiwan's Fair Trade Commission said that local companies had spent $30 billion on Qualcomm's wireless modems and that it had reaped NT$400 billion in licensing fees from Taiwanese companies over the last seven years. It has been violating antitrust laws for at least that long, the regulator said.

"The fine bears no rational relationship to the amount of Qualcomm's revenues or activities in Taiwan, and Qualcomm will appeal the amount of the fine and the method used to calculate it," the company said in a statement. Qualcomm intends to appeal the ruling, denying that it has violated neither local laws nor industry norms.

QUALCOMM, AN INTERNATIONAL BRAWLER, BEGINS BATTLE ON HOME SOIL

Qualcomm had been under investigation two years when the United States Fair Trade Commission sued it for violating antitrust rules right before the end of the Obama administration. The company, which is based in San Diego, Calif., had been seemingly safe on its home soil.

The agency said that Qualcomm had refused to supply chips to smartphone makers that did not agree to also pay for the underlying patents. The FTC claims that the company has also hoarded its standard-essential patents for 3G and 4G networks and refused to license them to customers in a fair, reasonable, and non-discriminatory way.

Qualcomm has denied the allegations, which include claims that Qualcomm gave discounts to smartphones makers using its product portfolio exclusively. The company said that it even if the allegations were true, they were not illegal. "The FTC does not have the authority to rewrite industry policy," Rosenberg said in a statement.

"That is for the industry, not a regulator, to decide," he said. Qualcomm plans to fight the lawsuit in court.

In June, a federal judge blocked Qualcomm's attempt to throw out the case. The Federal Trade Commission can proceed with its lawsuit, which Qualcomm takes issues with for another reason. Rosenberg pointed out that only three out of the five normal commissioners were available to vote on the decision.

SOUTH KOREA CHARGES QUALCOMM FOR TAKING ITS MONOPOLY TOO FAR

In December 2016, South Korea's regulator slapped Qualcomm with an $853 million fine for taking advantage of its monopoly over wireless modems to marginalize rivals and exploit customers. The Korean Fair Trade Commission ruled that the company had withheld chips from smartphone makers in the country that refused to also sign patent licensing deals.

The regulator also said that Qualcomm had taken advantage of its monopoly to strike licensing deals for its entire patent portfolio — overkill for many customers. The fine was also because Qualcomm refuses to license its standard essential patents to rivals that want to pay for them – hurting competition, the regulator said.

The ruling capped another $225 million that the Korean Fair Trade Commission fined Qualcomm in 2012. The regulator accused the company of giving rebates to companies that exclusively purchased chips from Qualcomm, which was also accused of charging higher royalty rates to smartphone makers that bought chips from rivals.

Both cases are under appeal with the Korean Supreme Court. The decision could have sweeping consequences for how and with whom Qualcomm negotiates licensing deals, potentially giving a boost to rivals Mediatek and Intel. But like Qualcomm's other legal battles, the lawsuits could still take years to finish.

QUALCOMM PAYS FINE TO STABILIZE ITS STANDING IN CHINA

In 2015, China's competition cops forced Qualcomm to pay $975 million in fines and renegotiate deals to take a smaller cut from devices sold by Chinese companies using its patents. The company and its investors looked at the regulatory whipping as the cost of doing business in China, which is Qualcomm's second largest market.

The regulator did not demand that Qualcomm change the patent licensing business, which contributes to a third of its annual profits. It actually helped stabilize its standing in the world's largest smartphone market, where it had struggled to collect royalties from Chinese firms. It is typically thought that Qualcomm charges 5% of the sale price of the device.

On Thursday, the company said that top Chinese smartphone vendors, including Lenovo and Xiaomi, had express interest in buying RF front end components with a total value of no less than $2 billion over three years. These include power amplifiers, envelope trackers, switches, discrete filters, antenna tuners, and other products. ■

TOOLS TARGET HYBRID SIMULATION of Radio Frequency Components

COMPUTER SIMULATION TECHNOLOGY recently released its latest software for simulating electromagnetic effects and interference caused by compact and complex electronic devices. The software breaks down the walls between the mathematical solvers inside it, giving it the power to more efficiently and quickly run through simulations.

That way, the CST Studio Suite 2018 software can simulate complex systems, like connected cars crammed with cabling behind the dashboard and radar systems installed in the bumpers, or sensors implanted under the skin to monitor vitals. It can also simulate radio frequency components like amplifiers and antennas inside them.

Computer Simulation Technology has traditionally competed by loading its tools with more algorithms based on Maxwell's Equations, which undergird all modern electronic circuits. But over the last few years, the company has reprogrammed its software so that these algorithms can be swapped out and used simultaneously in hybrid simulations.

"CST has long had industry-leading solver technology and in this new release we have leveraged synergies between them resulting in new powerful hybrid simulation methods," Peter Thoma, managing director of research and development for the Darmstadt, Germany-based firm, said in a statement.

The company said that its tools can simulate electromagnetic and circuit effects at the same time. With the assembly modeler function, the software can also model antennas and other parts pinned onto the complex circuit boards inside smartphones and connected cars. The components can be simulated simultaneously and the effects on each other measured.

The tools introduces new methods of meshing, or projecting triangular cells onto objects to prepare them for simulation, so that even models of the human body can move realistically to simulate breathing. The software also features an optimized filter design tool, allowing faster and more intelligent tuning for cross-coupled filters.

The new software underscores the rivalry between Computer Simulation Technology and its major suppliers in the market for electromagnetics software. One of its competitors, Ansys, recently expanded into software that can realistically playback simulations and that could be used eventually to test how antennas react to interference and dead zones.

Altair Engineering, its other major rival, which has targeted its software at systems like ships and airplanes, recently raised $156 million in an initial public offering of stock. That could give it more financial firepower to compete with Dassault Systèmes, the French software giant that bought Computer Simulation Technology for $242 million in 2016. ■

RADOMES PROTECT REFLECTORS from the Polar Frost

Satellite missions devoted to Earth observation (EO) have often involved polar orbits, along with the need to ground station terminals located in Arctic or Antarctic polar regions. But those ground station terminals must be protected from this planet's most severe environmental conditions when they are constructed in the polar regions. Especially as these satellite missions reach higher frequencies, such as K-band frequencies (25.5 to 27.0 GHz), the radomes must provide a combination of solid mechanical protection and reliable electromagnetic (EM) performance at the higher frequencies. The quest for radome materials for the latest EO satellite missions has involved detailed weather analysis to find the best compromise between mechanical and EM performance for these polar radomes.

The environmental conditions at polar latitudes are complex and extreme, making the evaluation of radome materials for polar earth stations quite difficult. Three factors, in particular, come into play when evaluating radome materials: the wind speed, the air temperature, and the amount of snow precipitation. A suitable test location for evaluating radome materials and the impact of these three factors was chosen in the Svalbard archipelago in the Arctic Ocean, at an approximate latitude of 78ºN. In support of the material experiments under these extreme weather conditions, details on the weather were provided by several weather stations, including the University Center in Svalbard, the Norwegian Meteorological Institute, and the Kongsberg Satellite Services (KSAT).

While details on some of the radomes that were studied remained proprietary to the companies providing the radomes, a great deal was learned by comparing different mechanical radome structures under these severe weather conditions. Constant high wind speeds, for example, can result in permanent deformation of a radome and require spare parts when a radome is expected to survive such extreme weather conditions.

The researchers used EM simulation software to better understand the impact of wind and precipitation on the EM transparency of different radome materials and mechanical designs, including how different types of membranes and panels are used in the design and construction of a radome. For satellite Earth stations located at the polar ice caps, this study certainly offers a great deal of insight into the importance of a radome configuration and the selection of its material content.

See "High-Frequency Radomes for Polar Region Ground Stations," *IEEE Antennas & Propagation Magazine*, Vol 59, No. 6, December, 2017, p. 88.

WR-3 BANDPASS FILTERS Cover 220 to 325 GHz

SOUNDERS FLOWN IN SPACE and in the air have been used for spectroscopic characterization of the Earth's atmosphere, performing molecular spectroscopy at millimeter- and submillimeter-wave frequencies. Filtering is an essential part of these systems, to prevent interference from unwanted sideband and interference signals in radiometers.

To learn more about achieving the best waveguide filtering performance at WR-3 frequencies from 220 to 325 GHz, researchers based at the University of Birmingham and other leading universities in the UK investigated two different fabrication methods for the filters: one of the filters was formed in metal by means of computer numerically controlled (CNC) milling and the other by means of metallized SU-8 photoresist technology. The filters were designed as potential replacements for the frequency-selective surfaces (FSSs) currently used for filtering in heterodyne radiometers employed for atmospheric characterization.

By using the two different fabrication approaches, the researchers could compare current versus potential future ways of building very high-frequency waveguide filters. CNC methods are well established for creating waveguide components, although they can be limited in machining resolution at extremely high millimeter-wave frequencies, and CNC milling methods can be expensive when forming precision waveguide components at very high millimeter-wave frequencies.

Both filter designs consist of three coupled resonators, and the SU-8 photoresist fabrication approach was used to form three silver-coated SU-8 layers. SU-8 is a photolithographically patterned, epoxy-based resin that can be cured with typical thicknesses ranging from 0.5 μm to 1 mm. This fabrication approach can form the waveguide features needed for millimeter-wave components with the same or greater precision and resolution as CNC machining, but at a fraction of the fabrication cost.

The researchers designed and constructed WR-3 bandpass filters with the two different fabrication approaches. They used CAE software for simulation modeling and commercial high-frequency vector-network analyzers (VNAs) for S-parameter measurements, using an analyzer from Keysight Technologies coupled with frequency-extension modules from Virginia Diodes to achieve the frequency coverage needed for characterizing the filters.

In spite of the two different fabrication approaches, the two bandpass filters both exhibit excellent insertion-loss and return-loss characteristics within the WR-3 frequency range, with close agreement between the measured results and the computer simulations. Given the cost of CNC machining at these frequencies and waveguide dimensions, the use of SU-8 photolithography certainly shows great promise for the future fabrication of high-frequency waveguide components.

See "WR-3 Waveguide Bandpass Filters Fabricated Using High Precision CNC Machining and SU-8 Photoresist Technology," *IEEE Transactions on Terahertz Science and Technology*, Vol. 8, No. 1, January 2018, p. 100.

DR. MILTON LIEN and DAVID VYE, | AWR Group, NI
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Count on Design Software for Millimeter-Wave Automotive Radar and Antenna System Development, Part 2

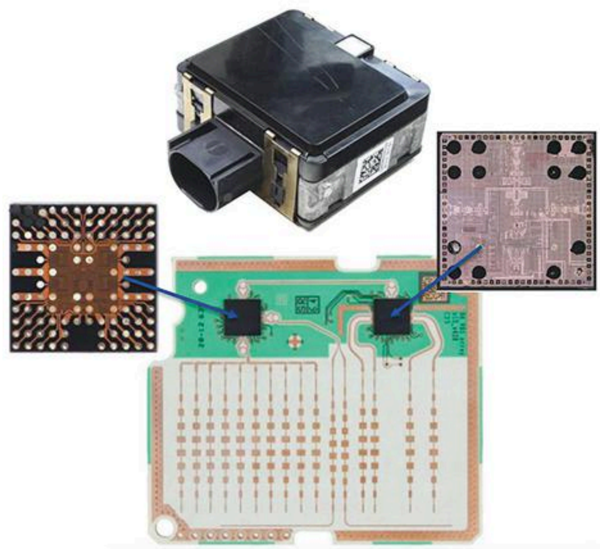
No question, automotive radar technology is reaching new heights. This article, part 2 of a two-part series, explains how the latest software can facilitate antenna design for the radar systems needed for next-generation cars and trucks.

Ongoing developments in advanced driver assistance systems (ADAS) are expanding the capabilities and affordability of vehicles that can alert and assist drivers using radar technology mostly focused over the 76-to-81 GHz spectrum. Part 1 provided an overview of ADAS systems and discussed various radar systems and architectures. Part 2 discusses multi-beam and multi-range design and examines antenna design for multiple-input, multiple-output (MIMO), and beam-steering technologies for 5G that will be useful for automotive safety in the future.

MULTI-BEAM/MULTI-RANGE DESIGN

A typical adaptive-cruise-control (ACC) stop-and-go system requires multiple short- and long-range radar sensors to detect nearby vehicles. The shorter-range radar typically covers up to 60 m with an angle coverage up to ±45°, allowing the detection of the vehicle's adjacent lanes that may cut into the current travel lane. The longer-range radar provides coverage up to 250 m and an angle of ±5° to ±10° to detect vehicles in the same lane, further ahead.

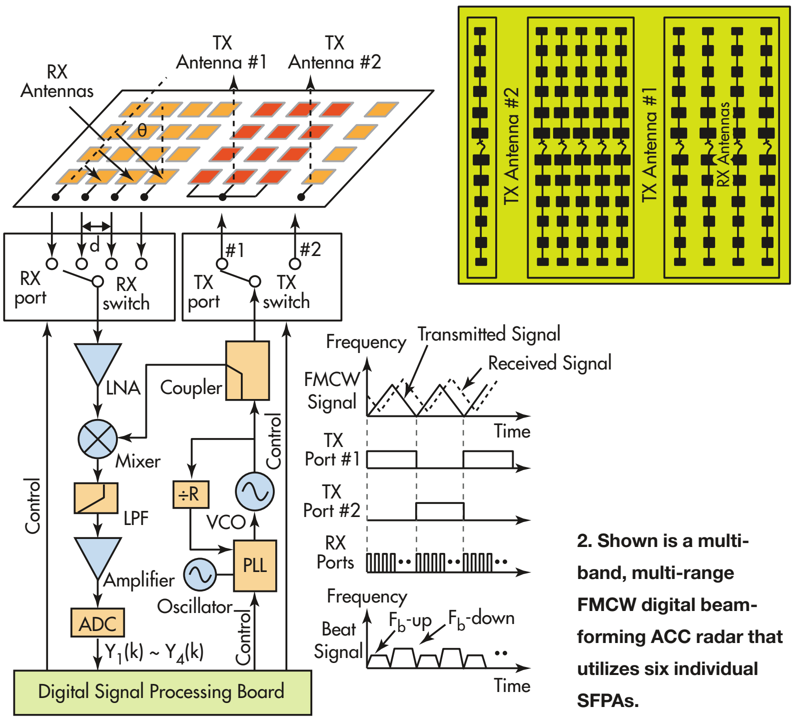
To support multiple ranges and scan angles, module manufacturers such as Bosch, DENSO, and Delphi have developed and integrated multi-range, multi-detection functionality into increasingly capable and cost-sensitive sensors using multi-channel transmitter (TX)/receiver (RX) architectures *(Fig. 1).* These different ranges can be addressed with multi-beam/multi-range radar by employing radar technology such as frequency-modulated-continuous-wave (FMCW) and digital beamforming with antenna-array design.



1. This mid-range radar sensor from Bosch features three transmitters and four receivers. It supports horizontal field-of-views of 160m (±6°), 100m (±9°), and 60m (±10°) for the main antenna, as well as 36 m (±25°) and 12 m (±42°) for the elevation antenna.

ANTENNA DESIGN

A multi-modal radar for an ACC system[1] based on an FMCW radar driving multiple antenna arrays is shown in *Fig. 2.* This multi-beam, multi-range radar with digital beamforming operates at both 24 and 77 GHz, utilizing two switching-array antennas to enable long-range, narrow-angle coverage (150 m, ±10°) and short-range, wide-angle coverage (60 m, ±30°). This example illustrates the use of multiple antenna-



2. Shown is a multi-band, multi-range FMCW digital beam-forming ACC radar that utilizes six individual SFPAs.

array systems, including multiple (5 × 12 element) series-fed patch arrays (SFPAs) for long-range, narrow-angle detection (77 GHz); a single SFPA (1 × 12 elements designed for 24 GHz) for short-range, wide-angle detection; and four (1 × 12) SFPAs for the receiver that was required for this type of system.

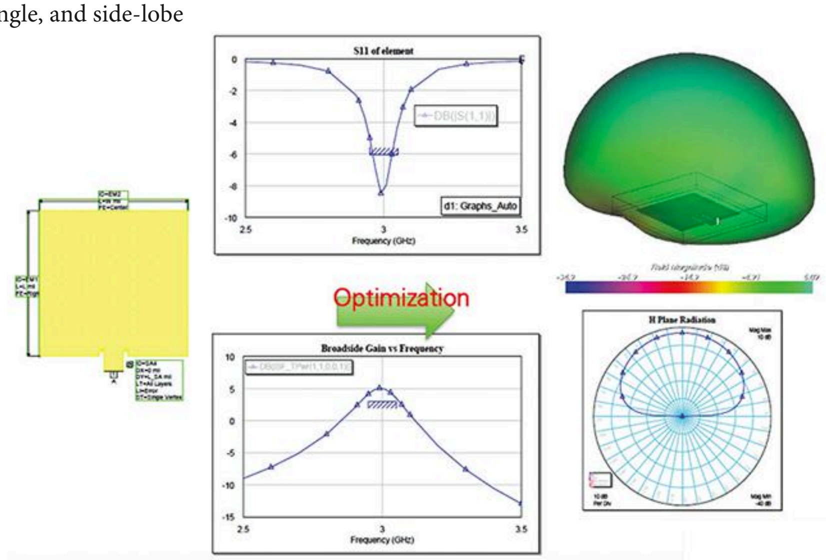
Radar performance is greatly influenced by the antenna technology, which must consider electrical performance such as gain, beam width, range, and physical size for the particular application. The multiple, fixed TX/RX antenna arrays in the example radar were optimized for range, angle, and side-lobe suppression. A patch antenna is relatively easy to design and manufacture and will perform quite well when configured into an array, which results in an increase of overall gain and directivity.

The performance of a rectangular patch antenna design is controlled by the length, width, dielectric height, and permittivity of the antenna. The length of the single patch controls the resonant frequency, whereas the width controls the input impedance and the radiation pattern. By increasing the width, the impedance can be reduced. However, decreasing the input impedance to 50 Ω often requires a very wide patch antenna, which takes up a lot of valuable space. Larger widths can also increase the bandwidth, as does the height of the substrate.

The permittivity of the substrate controls the fringing fields with lower values, resulting in wider fringes and therefore better radiation. Decreasing the permittivity also increases the antenna's bandwidth. The efficiency is also increased with a lower value for the permittivity.

Designing a single-patch antenna or array is made possible through the use of design software that utilizes electromagnetic (EM) analysis to accurately simulate and optimize performance. NI AWR Design Environment includes AXIEM 3D planar and Analyst 3D finite-element method simulators. In addition to simulating antenna performance such as near- and far-field radiation patterns, input impedance, and surface currents, these co-simulate directly with Visual System Simulator (VSS)—automatically incorporating the antenna simulation results into the overall radar system analysis without the need to manually export/import data between EM simulator and system design tools.

Both AXIEM and Analyst take the user-defined physical attributes of the antenna such as patch width and length, as well as the dielectric properties such as material and substrate height, to produce the electrical response. AXIEM is ideal for patch-antenna analysis, whereas Analyst is best suited for 3D structures such as modeling of a coaxial feed structure or finite dielectric (when proximity to the edge of a printed-circuit-board [PCB] would impact antenna performance; see *Fig. 3*).



3. This figure illustrates an example of an edge-coupled single-patch antenna optimized in AXIEM for center return loss and broadside gain to design frequency.

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ZVE-3W-83+	2000-8000	35	2	3	1424.95
ZVE-3W-183+	5900-18000	35	2	3	1424.95
ZHL-5W-2G+	800-2000	45	5	5	995
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• ZHL-16W-43+	1800-4000	45	12	16	1595
• ZHL-20W-13+	20-1000	50	13	20	1470
• ZHL-20W-13SW+	20-1000	50	13	20	1595
LZY-22+	0.1-200	43	16	30	1595
ZHL-30W-262+	2300-2550	50	20	32	1995
ZHL-25W-63+	700-6000	53	25	-	8595
ZHL-30W-252+	700-2500	50	25	40	2995
LZY-2+	500-1000	47	32	38	2195
LZY-1+	20-512	42	50	50	1995
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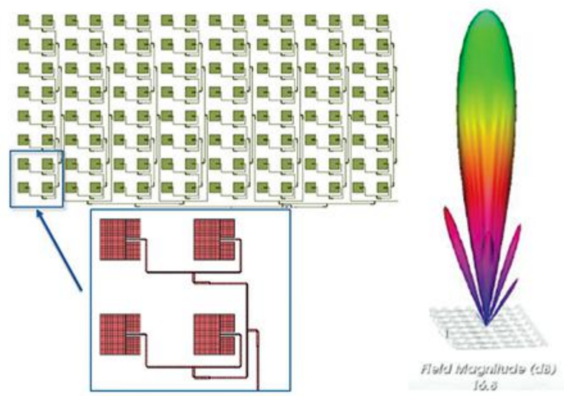
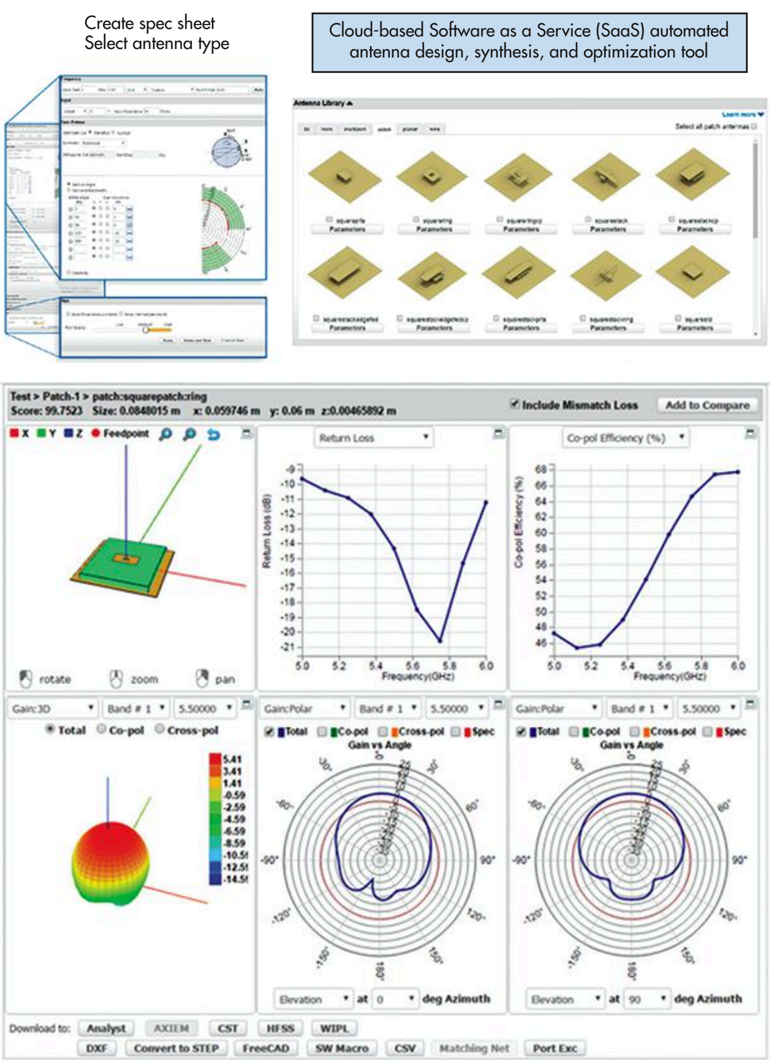


4. Shown is an 8 × 16 patch-antenna array (128-element) with corporate feed (single-feed port) and 167 k unknowns (1.88 GHz) solved in approximately 6.5 minutes with quad core.



5. This figure illustrates the AntSyn antenna synthesis specification interface and library of antenna types (a) and simulated results based on user-specified antenna requirements (b).

To determine the physical attributes that will yield the desired electrical response, antenna designers can use NI AWR software's AntSyn antenna synthesis and optimization tool *(Fig. 5)*.

Figure 4 shows a patch-antenna array with corporate feed and 167 k unknowns solved in less than 6.5 minutes with a quad core.

To determine the physical attributes that will yield the desired electrical response, antenna designers can use NI AWR software's AntSyn antenna synthesis and optimization tool *(Fig. 5)*. AntSyn enables users to specify the electrical requirements and physical size constraints of the antenna. The software explores a set of design configurations and determines the optimum structure based on proprietary genetic optimization and EM analysis. The resulting antenna geometry can then be imported in a dedicated planar or 3D EM solver, such as AXIEM or Analyst, for verification or further analysis/optimization.

Planar elements can easily form array structures by combining very simple elements such as microstrip patches. Patches can be configured in a series such as the 1 × 8 patch array in *Fig. 6*, where each element is connected serially by a "tunable" section of transmission line. In this AXIEM project, the lengths and widths of each array element and the connecting transmission lines were defined with variables to allow optimization of the overall array performance.

The 1 × 8 array can be further expanded into an 8 × 8 array for a high-gain fixed-beam design *(Fig. 7)*. This replicates the 8 × 8 element array reported in Ref. 2.

Within NI AWR Design Environment, arrays can be represented in VSS as a system behavioral block using the proprietary phased-array model that enables designers to specify the array configuration (number of elements, element spacing, antenna radiation

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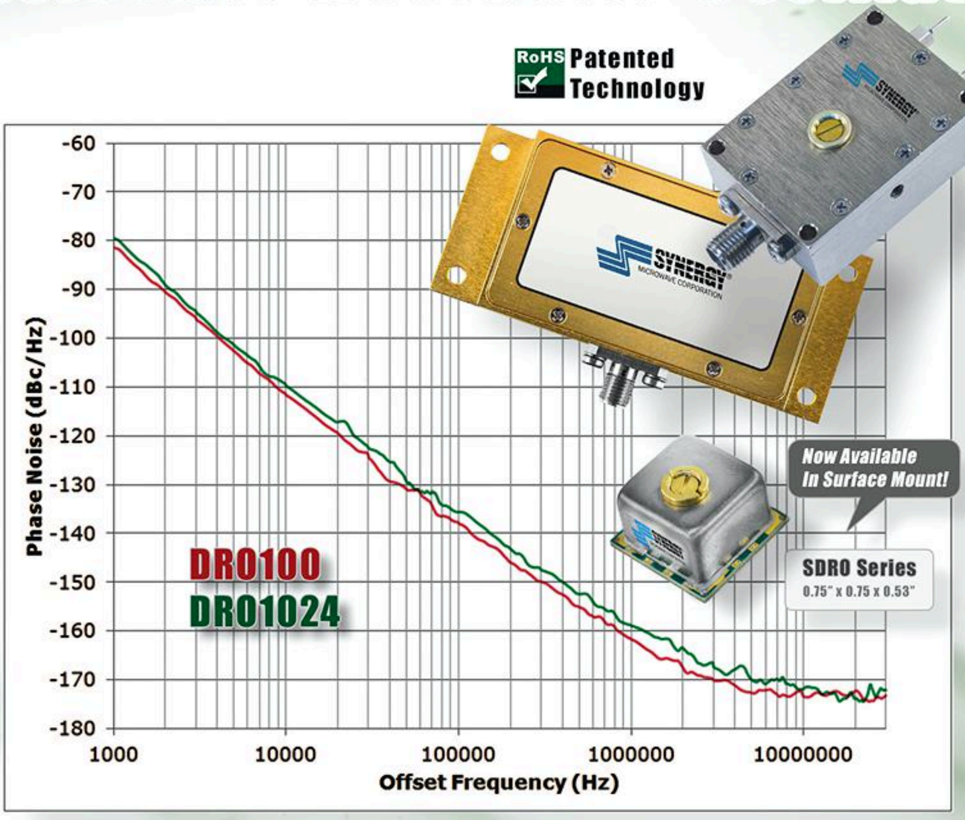

Model	Frequency (GHz)	Tuning Voltage (VDC)	DC Bias (VDC)	Typical Phase Noise @ 10 kHz (dBc/Hz)
Surface Mount Models				
SDRO1000-8	10	1 - 15	+8 @ 25 mA	**-107**
SDRO1024-8	10.24	1 - 15	+8 @ 25 mA	**-111**
SDRO1250-8	12.50	1 - 15	+8 @ 25 mA	**-105**
Connectorized Models				
DRO100	10	1 - 15	+7 - 10 @ 70 mA	**-111**
DRO1024	10.24	1 - 15	+7 - 10 @ 70 mA	**-109**

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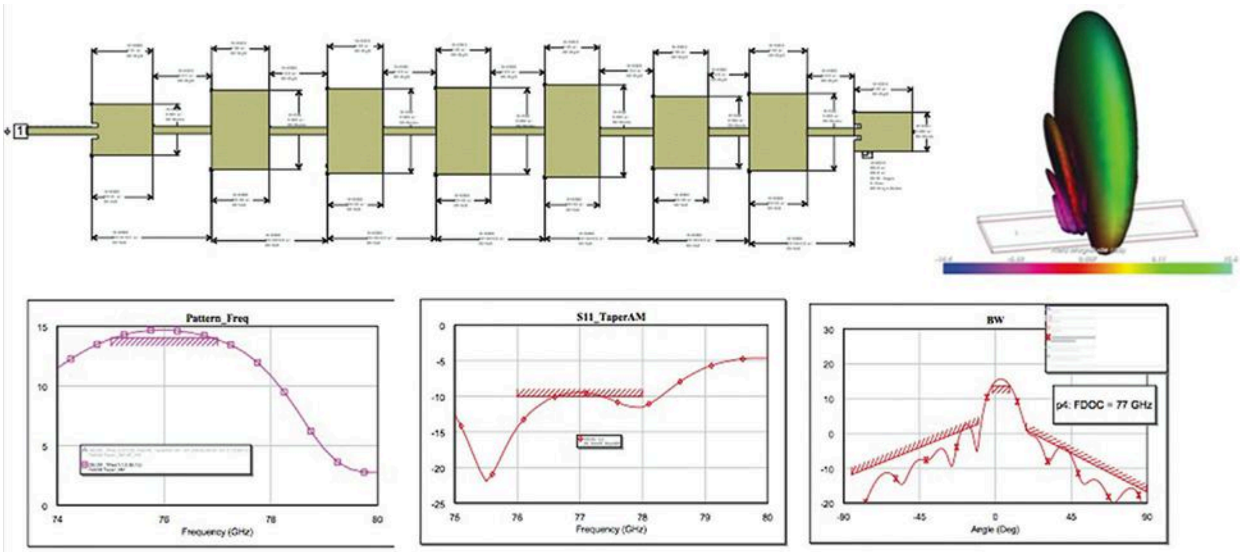


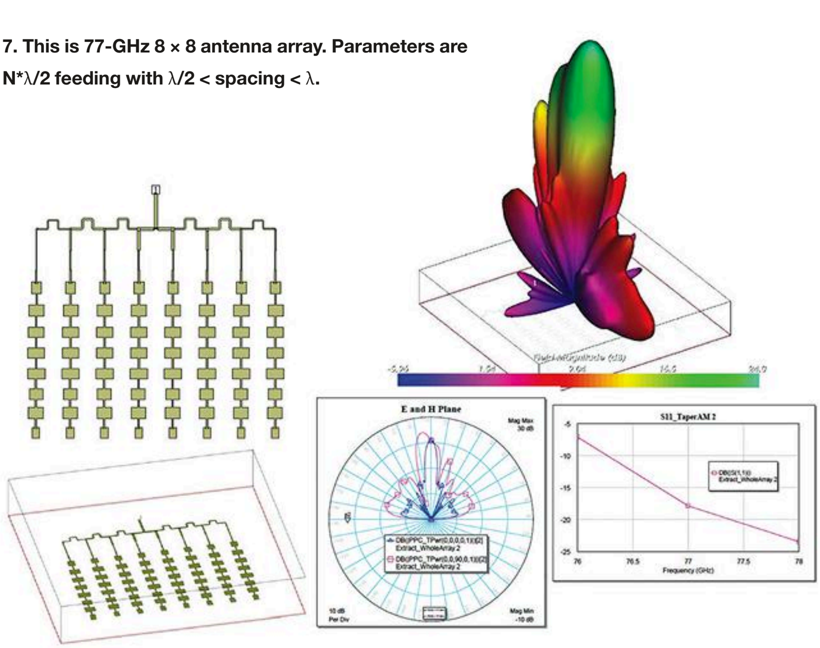
6. The software allows for the optimization of a series-feed 1 × 8 patch array with parameterized modifiers.

pattern, impaired elements, gain tapering, and more) for a high-level understanding of array requirements for desired performance such as gain and side lobes. This approach is best for large-scale arrays (thousands of elements) and system designers developing basic requirements for the antenna array team.

The array could also be modeled in AXIEM or Analyst with the detailed physical array, specifying individual port feeds *(Fig. 8)* or a single feed if the feed network is also implemented in AXIEM/Analyst *(Fig. 9)*.

This approach enables the design team to investigate the interaction between the beam angle and the input impedance of each individual element, allowing RF front-end component designers to account for impedance loading effects on transceiver performance. This capability highlights the importance of having RF circuit, system, and EM co-simulation to accurately investigate circuit/antenna behavior before fabricating these complex systems.

7. This is 77-GHz 8 × 8 antenna array. Parameters are N*λ/2 feeding with λ/2 < spacing < λ.

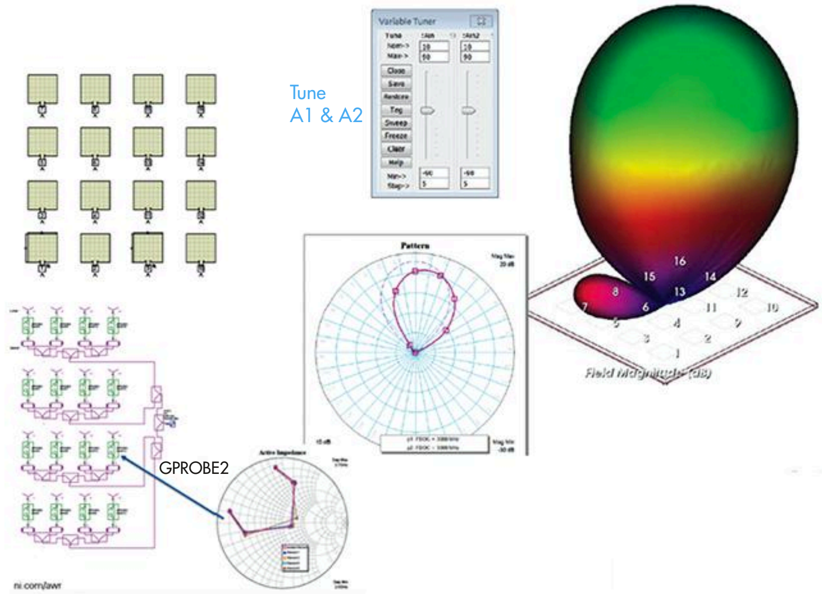


MIMO AND BEAM-STEERING ANTENNA TECHNOLOGIES

For road vehicles, a radar will receive unwanted backscatter off the ground and any large stationary objects in the environment, such as the sides of buildings and guardrails. In addition to direct-path reflections, there are also multipath reflections between scatterers, which can be used to mitigate the impact of clutter through the use of MIMO antennas.

A MIMO radar system uses a system of multiple antennas, with each transmit antenna radiating an arbitrary waveform independently of the other transmitting antennas. Each receiving antenna can receive these signals. Due to the different waveforms, the echo signals can be re-assigned to the single transmitter. An antenna field of N transmitters and a field of K receivers mathematically results in a virtual field of K·N elements, resulting in an enlarged virtual aperture that allows the designer to reduce the number of necessary array elements. MIMO radar systems thereby improve spatial resolution and provide a substantially improved immunity to interference. By improving the signal-to-noise ratio, the probability of detection of the targets is also increased.

VSS is able to implement user-specified MIMO algorithms and evaluate the overall performance as it relates to the channel model *(Fig. 10)*. Users can simulate a highly-customizable multipath fading channel that includes channel path loss, the relative velocity between the transmitter and receiver, and the maximum Doppler spread. Supporting independent or continuous block-to-block operation, the channel can contain multiple paths (LOS, Rayleigh, Ricean, frequency shift) that can be individually configured in terms of their fading types, delays, relative gains, and other applicable features. This module can also simulate a receiver antenna array with user-defined geometry, enabling simulation of single-input, multiple-output (SIMO) systems.



8. Shown is a 4 × 4 patch-antenna array with individual ports for each element, enabling the feed structure (lower left) to be defined and co-simulated at the circuit/system level to monitor the changing antenna input impedance per element and control beam steering through the RF feed network.

CONCLUSION

Aside from becoming more sophisticated and reliable, ADAS systems will become more prevalent on most (if not all) vehicles in the not-too-distant future. Thanks to the similar advances in antenna-array and millimeter-wave technology that are occurring in 5G communications, most cars and trucks will be considerably safer than they are today. Advances in simulation technology—particularly in RF-aware circuit design, array modeling, and system-level co-simulation—will enable antenna designers and system integrators to optimize these systems for challenging size, cost, and reliability targets. mw

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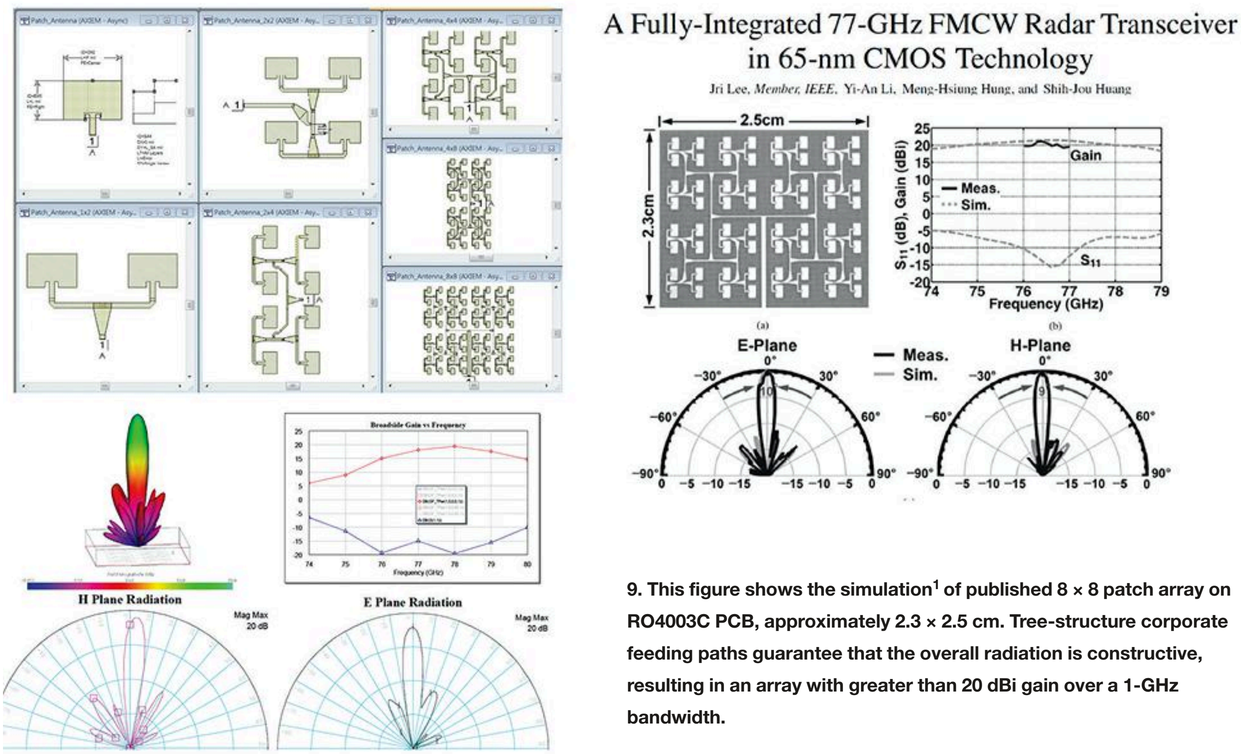
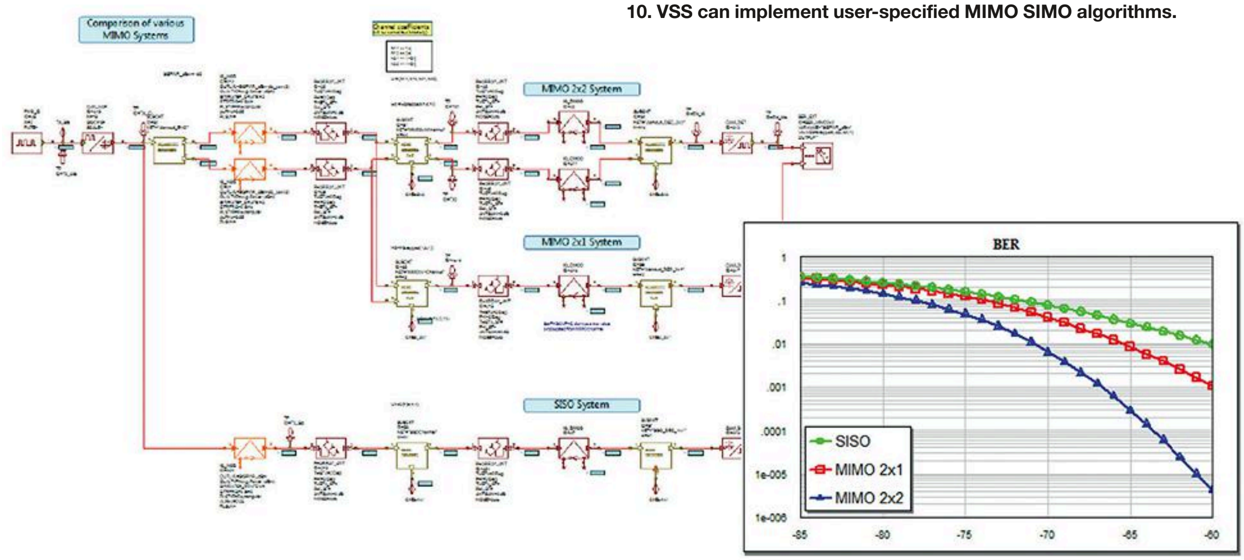


9. This figure shows the simulation[1] of published 8 × 8 patch array on RO4003C PCB, approximately 2.3 × 2.5 cm. Tree-structure corporate feeding paths guarantee that the overall radiation is constructive, resulting in an array with greater than 20 dBi gain over a 1-GHz bandwidth.

10. VSS can implement user-specified MIMO SIMO algorithms.



JACK BROWNE | Technical Contributor

Satellites Provide Distant Connections

The growing number of artificial satellites—notably those with low earth orbits—is a sign of the essential roles that they will play in many emerging communications applications, including IoT, 5G, and connected cars.

1. Artificial satellites were once entirely geosynchronous-earth-orbit (GEO) types at high altitudes and with larger cover areas, but the current trend is for using larger numbers of smaller low-earth-orbit (LEO) satellites at lower altitudes and smaller coverage areas. *(Courtesy of Telesat)*

Satellites have become a well-established contributor to modern electronic communications. RAF officer and science fiction writer Arthur C. Clarke is often credited (in 1945) with the concept of communications by means of relaying signals back and forth between the earth and orbiting artificial satellites. Satellite communications (satcom) systems have evolved a great deal from that early idea, growing into the many different satellite constellations at different orbiting altitudes that are currently serving many different markets and applications.

Today's satellites are commonly categorized as the earliest geosynchronous earth orbit satellites (GEOS), medium earth orbit satellites (MEOS), and the latest, low earth orbit satellites (LEOS). The latter are soon to become key parts of the emerging 5G wireless communications network, which will promise delivery of high-speed, wideband data anywhere and anytime, and those satellites will help make it anywhere. Satellite is the only electronic communications technology that can reach 100% of the earth's population.

A satellite's payload defines the type of application for which it is best suited, such as military signal intelligence (SIGINT), commercial communications or broadcast, and specialized applications such as weather forecasting. A communication satellite's payload includes a transponder, which is a transmitter and receiver operating at a designated frequency band. Satellites can have circular or elliptical orbits, maintaining the same distance above the earth in a circular orbit and having that height above the earth vary with an elliptical orbit. The height above the earth provides satellites with the capability to transmit and receive radio waves over great distances compared to communications systems using line-of-sight (LOS) signals.

Early satellites had mostly passive payloads, serving essentially as repeaters for signals transmitted from earth and redirecting the signals back to earth at much lower power levels, due to the attenuation from free-space signal loss. Most current satellites employ active transponders with high-gain amplifiers on board to overcome free-space path loss and typically increase the power level of signals being retransmitted to earth.

The antennas onboard a satellite must receive uplink signals from earth with high sensitivity and transmit downlink signals back to earth with high gain. A number of different antenna types are used on satellites, including dipole antennas for omnidirectional transmissions and reception, and highly directional antennas for telecommunications and broadcasting. Directional antennas are usually more recognized for their associated surrounding reflector assemblies (as in direct broadcast television antennas), which support antenna gain and directivity.

A satellite's antenna patterns are designed to cover a specific area on the earth. On the earth's surface, earth stations are designed to control the satellite should it drift from its designated position due to various external forces, including the gravitational forces of the moon and the sun. Due to the distance from the surface of the earth, the gravitational force of the earth has no effect on a geosynchronous satellite. There is some centrifugal force due to the rotation of the earth that can cause them to deviation from their position.

A satellite's elevation angle, ε, is typically defined as the angle from the center of the satellite's radio beam and a plane tangential to the earth's station. A satellite's footprint is the area on the earth within which receivers with standardized specifications can receive and process signals from the satellite. Satellites at different orbital heights, such as a GEOS and a LEOS, will achieve different footprints, requiring a different number of satellites in a constellation to achieve a given coverage area for an application.

For example, geosynchronous satellites have circular orbits that follow the movement of the earth. For a stationary observer on the surface of the earth, a geosynchronous satellite will appear to be fixed in space. Because of its height above the surface of the earth (just over 22,000 miles in altitude in an orbit that is at 0 deg. latitude, at the equator), a geosynchronous satellite has an extremely large footprint. As a result, it is possible to achieve total coverage of the earth with only three geosynchronous satellites in a constellation.

Such satellites orbit with the same rotational speed as the earth and in its eastward direction of motion, fixing them in their designated location above the earth's surface. The inclination of a geosynchronous satellite with respect to earth is 0 deg. Such high-orbiting satellites are commonly used for radio and telephone broadcasting, as well as for wireless telephone networks.

When used for voice communications, the lower orbital heights of LEOS and MEOS provide advantages in terms of signal delay times. Because of the significant distances that a signal must travel from the ground to the satellite and back down to the ground, there is considerable delay time for satellite communications signals from a GEOS, which is most noticeable during satellite telephone voice calls. The shorter distance that a signal must travel from the earth's surface to a LEOS and back again translates into considerably less latency for a LEOS than for a GEOS. The smaller footprints of LEOS compared to GEOS allows for better frequency reuse in a LEOS constellation than in a GEOS system—although for a given coverage area, a GEOS system can be implemented with considerably fewer satellites and earth stations.

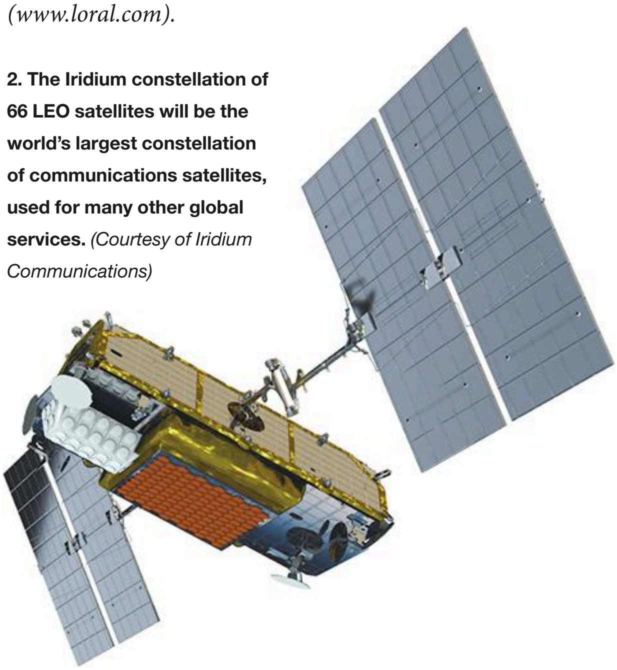
SORTING SATCOM FREQUENCIES

A wide range of frequencies has been allocated for satellite use by global standardization organizations such as the U.S. Federal Communications Commission (FCC) and the International Telecommunication Union (ITU). Allocations must be with international agreement to prevent frequency overlaps and interference. Frequency bands are allocated for fixed satellite services, mobile satellite services, broadcast services, meteorological satellite services, and navigational services using GPS satellites, with allocations covering a wide total frequency range from VHF and UHF through millimeter-wave (30 to 300 GHz) frequencies and higher.

For example, late last year, the FCC granted a petition from Canadian-based Telesat *(www.telesat.com) f*or access to the U.S. satcom market using Telesat's growing LEO satellite constellation *(Fig. 1)*. With this FCC approval, and prior rights from the ITU, Telesat has obtained worldwide rights to about 4 GHz of Ka-band frequency spectrum for their LEO satellite system. This is enough bandwidth to support numerous broadband services.

The company has stated its intention to create a massive LEO satellite constellation of around 120 satellites by 2021; as part of reaching that goal, the company is planning to launch two satellites in 2018: Telestar 18 VANTAGE over Asia and Telestar 19 VANTAGE over the Americas. The LEO satellite system is being assembled to provide broadband voice, video, and data services for government, business, and individual users, as part of a business decision to build upon LEO satellites rather than GEO satellites as a more flexible and practical satcom solution.

"Telesat applauds the FCC's ruling, which will bring manifold benefits to the U.S. market, including improved access to the internet as well as the potential to enhance opportunities for U.S. workers and consumers, U.S. industry, and the U.S. technology base," said the company's president and CEO, Dan Goldberg. "Next-generation LEO satellite constellations have great promise for erasing the digital divide, and Telesat encourages the FCC, as it reviews its spectrum allocation policies, to ensure that satellite operators have sufficient access to the spectrum necessary to deliver on that promise." It should be noted that, although Telesat is a Canadian company, 62.7% of the company is owned by a U.S.-based satcom company, New York-based Loral Space & Communications *(www.loral.com)*.



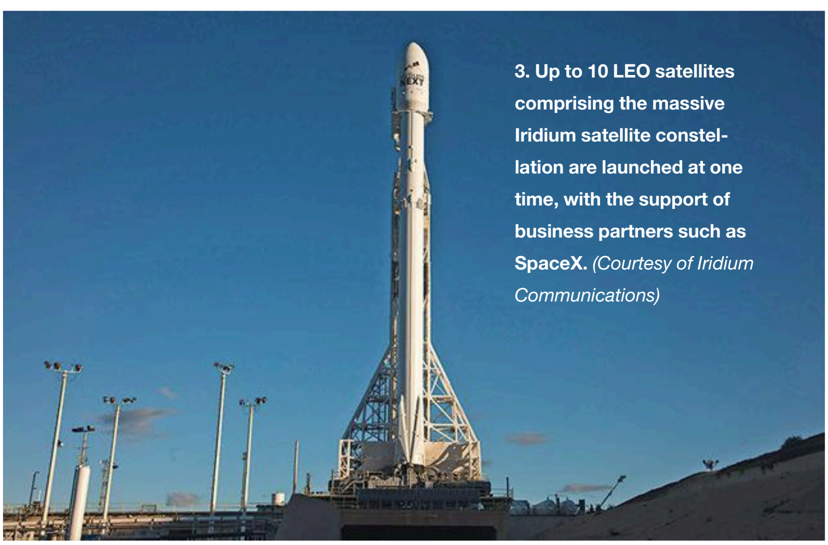
2. The Iridium constellation of 66 LEO satellites will be the world's largest constellation of communications satellites, used for many other global services. *(Courtesy of Iridium Communications)*

LEOS LOOM LARGE

The Telesat LEO satellite constellation will offer competition to the current state-of-the-art LEO satellite constellation managed by Iridium *(www.iridium.com)*. The company's second-generation Iridium-NEXT satellites *(Fig. 2)* form the world's largest satellite constellation. Its 66 cross-linked LEO satellites, providing mobile voice and data service across the entire planet, including the oceans and the polar regions. The Iridium NEXT LEO satellites are deigned to provide seamless coverage and a dynamic mesh network, with each Iridium NEXT satellite linked to four nearby satellites, two in the same orbital plane, and one in each adjacent plane.

This mesh network routes traffic among satellites to ensure a continuous connection, everywhere. Each satellite communicates with nearby satellites to create a totally continuous satcom network. Combined with redundancies across the network, secure, dedicated ground infrastructure, and low interference at L-band frequencies, this unique configuration will allow services using the Iridium network to continue to remain unaffected by natural disasters—including hurricanes, tsunamis, and earthquakes that can cripple terrestrial infrastructure. These LEO Iridium satellites are typically placed in orbit by rockets that carry as many as 10 satellites at one time *(Fig. 3)*.

The trend away from GEO satellite constellations and towards LEO satellite constellations is quite clear with these activities by Telesat and Iridium Communications. In addition, LEO satellites will play important roles in the infrastructure of emerging 5G wireless communications networks, especially as service providers look to the satellites to provide affordable wireless communications services in remote regions that are not practically serviced by the erection of terrestrial cellular-type base stations.



3. Up to 10 LEO satellites comprising the massive Iridium satellite constellation are launched at one time, with the support of business partners such as SpaceX. *(Courtesy of Iridium Communications)*

Many of these LEO satellites contributing to 5G services may also be sending and receiving signals at millimeter-wave frequencies, requiring specialized antenna designs and high-frequency transponders in addition to lower-frequency equipment. Since LEO satellites have relatively small footprints compared to GEO satellites, the visibility for a mobile communications user on earth to be within range of a LEO satellite in a 5G network will be only minutes per satellite, requiring efficient, high-speed switching and seamless connectivity between satellites to make such switching invisible to mobile users on earth. mw

JACK BROWNE | Technical Contributor

Comparing Narrowband and Wideband Channels

Narrowband and wideband communications channels make use of available bandwidth in different ways—so employ them according to the requirements of a particular application.

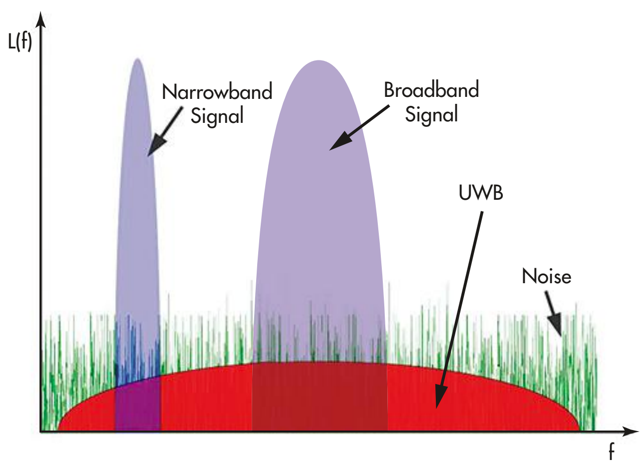
Bandwidth is limited at all frequencies. This holds true whether we're discussing those in the kilohertz range used for amplitude-modulated (AM) radio broadcasting; microwaves and millimeter waves for commercial and military radar systems; or those frequencies bands with the shortest-wavelength electromagnetic (EM) signals, including infrared (IR), ultraviolet (UV), x-rays, and gamma rays.

No single component, such as a filter or amplifier, has enough bandwidth to handle them all. But some components are designed for more narrowband use while some are wideband and can process (for example) a number of different communications frequency bands at the same time. It might make economic sense to use a single amplifier or filter rather than two of each to tackle two different frequency bands in a system. But just what are the tradeoffs (other than cost) in using wideband rather than narrowband components in an RF/microwave system?

Narrowband communications channels have long been used in many applications that have depended upon achieving reliable links in different operating environments, such as in tactical military radios and industrial monitoring purposes. But as more information must be conveyed between two points by wireless means, such as for video streaming and advanced surveillance systems, wideband communications channels with their greater data capacities become more attractive.

In terms of transmitted and received signal information, more bandwidth translates into higher data rates. For instance, depending upon the speed of available analog-to-digital converters (ADCs) and digital-to-analog converters (DACs), achieving a data rate of 1 Gb/s with a wireless communications system will require at least 100 MHz of contiguous bandwidth. However, finding that much contiguous bandwidth in today's crowded spectral environment can be quite difficult, especially at lower frequencies.

This is one of the several reasons why planners of the emerging 5G wireless communications network are looking to millimeter-wave frequencies and their available bandwidths in support of high-speed data communications links, both for terrestrial links and those incorporating low-earth-orbit (LEO) satellites. Transmitting and receiving more voice, video,



Narrowband signals occupy much less frequency spectrum and require less transmit power for a given application than wideband signals, while UWB signals are short pulses that send information while briefly occupying a large portion of the traditional communications frequency spectrum.

and data over wider-bandwidth frequency channels comes at a cost, however, since wider sections of frequency spectrum also contain greater numbers of noise sources and higher levels of noise *(see figure)*.

In contrast to narrowband channels, where the amount of noise within the channel is limited by effective filtering to suppress any noise and interference outside of the frequency band in use, wideband channels can limit the noise appearing at frequencies outside of the channel. However, any signals that are transmitted within the band must compete with the noise floor of that section of spectrum.

As a result, typically higher transmit signal power is needed in a wideband channel to overcome the noise level—as well as other factors, such as signal propagation losses—so that a significant signal level will appear at the receiver and meet the receiver's minimum signal-to-noise-ratio (SNR) performance requirements for reception and processing.

In short, wideband channels can carry more information than narrowband channels, but they typically require more power to do so. Narrowband channels typically carry much less information than wideband channels and operate over shorter distances between transmitter and receiver. But because narrowband channels have less noise and typically lower noise floors (depending upon the channel bandwidth) than wideband channels, they require less transmit power levels than communications systems with wideband channels and can typically operate with lower transmitter and receiver power supplies than communications equipment with wideband channels at nearby frequencies.

In fact, the lower operating-power requirements of narrowband communications equipment often makes it the preferred solution for applications that require transmission of limited information over relatively short distances, but may require operation by means of battery power, such as in a portable and/or mobile electronic device.

The frequencies intended for different communications (and other) systems are tightly orchestrated and allocated by federal organizations within a country, such as the U.S. Federal Communications Commission (FCC) and the International Telecommunications Union (ITU). Without this control, it would be possible for multiple signals from different applications to occupy the same segment of bandwidth, such as tuning to a frequency channel on an AM or FM radio and receiving two broadcast stations at the same time (and not being able to make sense of either station).

Similarly, two different radio communications systems with different center frequencies, but with overlapping bandwidth, will serve as interference sources for each other, depending upon such factors as transmit power and receiver selectivity and sensitivity. If the sensitivity of one radio is high enough to detect a signal that falls within its bandwidth, that outside signal will act as interference. For this reason, both center frequencies and their bandwidths must be monitored and controlled.

WHAT ABOUT USING UWB COMMUNICATIONS?

TRADITIONAL ELECTRONIC COMMUNICATIONS SYSTEMS have employed wideband channels, narrowband channels, and sometimes a combination of both, with different types of signal modulation typically based on changes in amplitude, frequency, or phase. But pulses have also been used in a form of communications system known as ultrawideband (UWB) communications.

In UWB communications systems, information is transmitted and received over wide bandwidths, typically greater than 500 MHz or 20% of the arithmetic center frequency (such as 200 MHz of 1 GHz), in a way that will not interfere with conventional narrowband and wideband communications systems, sharing the same spectrum among many users. Once known as pulse radios, UWB radios transmit short pulses at low power levels which occupy a wide designated bandwidth. They may operate at low or high pulse repetition rates (PRRs).

In contrast to conventional communications systems which transmit information by varying a sinusoidal signal's amplitude (in amplitude modulation), frequency (frequency modulation), or phase (phase modulation), UWB pulses occupy a wide bandwidth by use the timing of the pulses to transfer large amounts of information, although by also occupying a large bandwidth for those short durations.

Some UWB communications systems are designed to transfer information by encoding the polarity of a pulse, by changing its amplitude, or even by using orthogonal pulses. Other UWB systems are designed to send pulses sporadically, while still others transmit pulses continuously, at pulse rates exceeding 1 Gpulses/s for high-capacity (high-data-rate) transmissions.

UWB communications technology has never become widespread, in part because of availability of building-block components (such as wideband mixers and amplifiers) and concerns about interference with existing narrowband systems where a short pulsed signal at sufficient energy level could block the reception of a low-level narrowband signal. Although UWB communications technology provides the means for relatively long-distance communications, its most practical use may develop as a short-range solution for wireless applications requiring transmission of large, high-speed data rates.

In terms of practical applications, if given an available portion of spectrum (such as 100 MHz), does it make more sense to use the entire radio bandwidth in one application or to break it into multiple applications? In some cases, such as in pulsed ultrawideband (UWB) communications systems, most of the available bandwidth may be used at extremely low power levels to send a great deal of information, albeit transmitting for very short pulse periods *(see sidebar)*.

Different wireless applications have different electrical performance requirements. Narrowband communications channels are limited in the amounts of instantaneous voice, video, and data they can carry compared to wideband channels. The movement of a receiver and/or transmitter, as in a mobile wireless radio application, can also impact the capability of a narrowband receiver compared to a wideband receiver attempting to detect higher broadband signal levels. Narrowband radio channels are typically used for shorter-range, fixed-location wireless applications, such as radio-frequency identification (RFID) and commercial vehicle remote keyless entry (RKE) devices.

MAKING ENDS MEET

In cellular communications networks (e.g., the 4G LTE systems currently in service), a variety of relatively narrow bands are employed to support different service applications, including emergency service functions. While this use of narrow bands within the available spectrum helps to minimize interference, it poses challenges to infrastructure and mobile device manufacturers to specify suitable components for devices in each band without having to acquire an enormous volume of inventory in components—such as receiver and transmitter components—to support a different block diagram for each cellular service band.

A number of component and integrated-circuit (IC) suppliers for modern wireless communications systems that employ any number of multiple narrowband channels, including Skyworks Solutions *(www.skyworksinc.com)*, have turned to integrating the functionality for multiple frequency bands within a single IC or module. As an example, the SKY13713-21 from Skyworks is a low-noise-amplifier (LNA) diversity module capable of supporting multiple wireless standards and narrower frequency bands using a single device.

It is supplied in a compact surface-mount package for ease of installation in a portable, mobile device, such as a manpack radio or cellular telephone, and allows switching among different operating frequencies and cellular service bands (including 3G and 4G cellular bands), so that one part can be used for many different block diagrams. The integration of front-end components, such as amplifiers and filters, within a single component for these different narrowband designs eases inventory issues for system integrators and manufacturers. It also provides a practical solution for designing communications systems with dedicated or multiple narrowband frequency ranges.

Both narrowband and wideband communications channels have their purposes, and components and modules are needed for both approaches, since they will support different applications. As noted, the multiple-function promises of 5G wireless communications networks with their "instant data and video" assurances will require wideband channels—and for many of them, so much so that 5G system planners are reaching into millimeter-wave frequencies with their wide bandwidths for the capacity to carry all the information expected to be carried through 5G wireless networks.

But 5G is only one of a number of emerging global wireless applications expected to change the world, with such applications as "connected cars" and Internet of things (IoT) sensors sending data to the Internet wherever they can provide information. The potentially billions of IoT sensors that will require wireless connectivity for access to the internet will, for the most part, be sending their data by means of narrowband channels, at whatever frequencies those channels can be formed. The need for front-end components and integrated front-end modules will only grow during the next few years, as the applications for both wideband and narrowband channels continue to expand, and this truly starts to become "a wireless world." mw

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Rotman Lens' Electronic Beam Steering Aims At 5G Signals

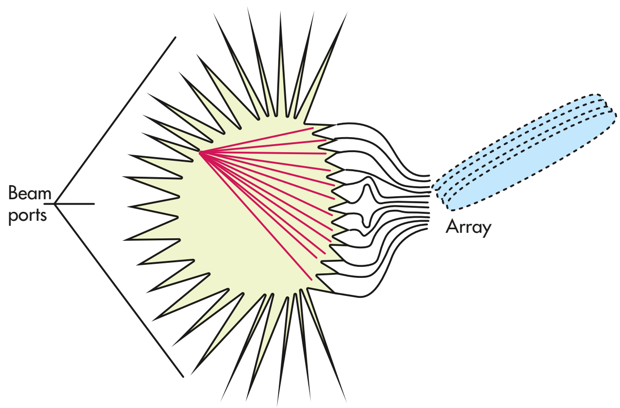
This novel antenna configuration provides an inexpensive means of sending and receiving the millimeter-wave signals needed for moving large amounts of data in 5G wireless networks.

Mobile wireless communications is heading toward its fifth generation (5G) with about as much fanfare as ever afforded a new group of technologies. Much of the excitement is due to the growing desires of wireless communications users for receiving such information as instant video and larger data files without delay. The massive improvements of 5G over the legacy wireless communications system, 4G Long Term Evolution (LTE), promise to deliver all that wireless users want and more, even to the extent of reaching to millimeter-wave frequencies for additional bandwidth.

What may be the most ironic part of the big build-up to 5G is the fact that there are yet no established standards in terms of modulation schemes, frequencies, and bandwidths. But one thing is for certain: Bandwidth will be needed, and millimeter-wave frequencies do not (as of yet) suffer the congestion of the many wireless applications found at lower frequencies. Millimeter-wave frequencies used in 5G and key components, such as antennas, will be needed for those high-frequency communications links. One promising solution for the antennas in those millimeter-wave links is the Rotman lens.

Precisely which millimeter-wave frequencies and bands will be used for 5G networks is not known as of yet, but different component and systems manufacturers are promoting the use of different frequencies; these include 28, 50, 77, and even 102 GHz. Components and subsystems at these frequencies have long been used in military applications for secure short-range line-of-sight communications links and for radar systems. More recently, they have been adopted by commercial vehicle manufacturers for collision-avoidance radars in automotive safety systems. For 5G wireless networks, which will combine nodes from satellite communications (satcom) systems and terrestrial, cellular base stations, users will experience a seamless and integrated network.

For example, in a more densely populated area such as a city, a user will connect to the network by means of cell sites. Outside of the city—in suburbs or the countryside, where lower populations offer less justification for erection of cell sites—users can connect to the 5G network by means of satcom system. When entering a building within the city, the user may even gain network access through a Wi-Fi wireless connection. The user will not notice any of the hand-offs and will not have to log onto the network when hand-offs are made. Of course, to make 5G work this effectively new hardware will be needed at higher operating frequencies than employed in current 4G LTE networks.



1. The operation of a Rotman lens is shown here. In receive mode, energy is focused on one of the beam ports, whereas in transmit mode, energy is directed in the array in the desired direction by feeding the signal into the appropriate beam port.

Some 5G infrastructure developments may result from the following considerations:

1. Several companies are planning to launch networks of low-earth-orbit satellites (LEOS) or mega-constellations of satellites. These satellites are likely to be at Ka-band frequencies to achieve large data throughput and operate with acceptable

levels of atmospheric signal absorption. Each satellite will be "visible" to a mobile device for 10 to 15 minutes before the device must be switched over to an adjacent orbiting satellite. Many LEOS are needed to provide wide geographic and continuous coverage.

2. For 5G, Wi-Fi is likely to be at 60 GHz where there is a high level of atmospheric absorption resulting in limited signal propagation distance. The 4-GHz bandwidths available at that frequency support data rates to 15 GB/s.
3. Backhaul links are likely to be at E-band frequencies, which will support similar data rates at propagation distances to 15 km.
4. Mobile communications units will rely on satcom, Wi-Fi, and terrestrial-based wireless network connections, with the main uncertainty having to do with the operating frequencies for the wireless network.

MAKING WAVES

While the exact frequencies that will be used for 5G systems may not as of yet be known, it is clear that higher frequencies, in the millimeter-wave frequency range, will be used to deliver the large amounts of data at high transmission speeds that are the looming characteristics of 5G wireless communications networks. As communications frequencies increase, communications systems and their components must comply with the requirements. For example, smaller signal frequencies require the use of components designed for the smaller wavelengths of those higher frequencies and changes in the way that signals propagate. A 4G cellular telephone operating at 2.1 GHz will suffer considerably less atmospheric absorption of signal power that a 5G cellular telephone operating at 77 GHz.

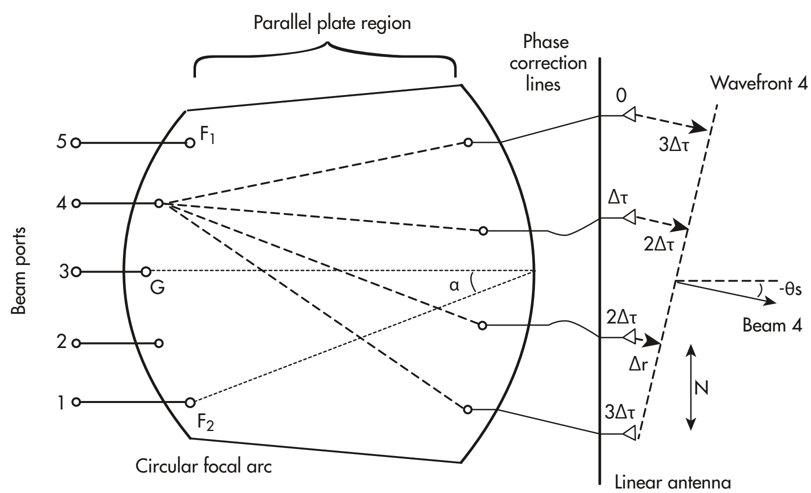
As a result, many more access points or base stations will be needed for millimeter-wave systems than for microwave wireless systems, thousands compared to hundreds for a given application region. The signal beams are much narrower at the higher frequencies, so beam steering technology is essential for capturing as much of a wireless signal beam's energy and its data as possible. The Rotman lens represents a special and inexpensive means of performing beam steering at millimeter-wave frequencies.

The Rotman lens, named after Walter Rotman, was developed by Rotman and R.F. Turner in 1965.1 The true time delay (TTD) was first designed for use in radar systems at relatively low frequencies (around 3 GHz), where it provides multiple-beam operation and the capability to simultaneously detect targets in different directions without moving the antenna system. The Rotman lens antenna is a key component in many radar and electronic-warfare (EW) systems for its unique beam-steering characteristics. A Rotman lens works by orchestrating reflections in a "lens" structure having phase shifts such that the direction of the output array transmission depends upon the input direction of the incoming beam. With careful design, gains of 10 to 15 dB are possible.

The Rotman lens features a number of input (or beam) ports, a lens cavity, and a number of output (or array) ports, which are each connected through "phase correction" lines to a radiating element in an antenna array (*Fig. 1*). When the lens is excited at one of the beam ports a tilted beam is radiated from the array. By switching between input ports, the radiated beam can be scanned through the lens' field of view.

To achieve a high angular resolution between beams, a large number of beam ports are required. This can lead to a requirement for a high component count on the input side of the lens, as well as high spill-over losses due to small port widths (spill-over loss occurs when some of the signal being transmitted between the lens beam and array ports is incident on the sidewalls of the lens which are lined with absorber or dummy ports to prevent internal reflections; this causes a loss of signal power). The Arralis design includes a method of improving the angular resolution of a Rotman lens beamforming network while reducing the component count and system losses, without causing any significant change to the overall size.

The geometry of a conventional Rotman lens is shown in *Fig. 2*. A number of input (beam) ports are situated along a focal arc at one edge of the parallel plate region, with a number of output (array) ports located on the opposite edge. The array ports are connected to an array of radiating elements (or antennas) through phase correction lines of unequal length. When the lens is excited at one of the beam ports, a signal propagates through the parallel plate region, is sampled by the array ports, and transmitted via the phase correction lines to the array elements which radiate the signal into free space.

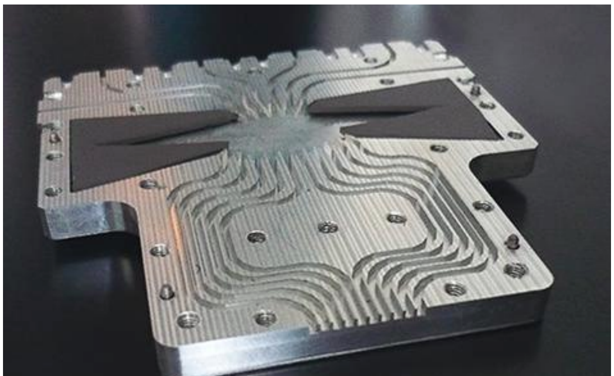


2. This diagram illustrates the multiple ports and the essential operating parameters of a Rotman lens.

The propagation path lengths from the beam port under excitation to the antenna elements provide a progressive linear time delay across the array. Due to constructive interference, a delay of $\Delta\tau$ between adjacent elements, separated by a distance of N, produces a radiation pattern at a scan angle, θs, relative to the central axis.

$$\theta s = \sin^{-1}[(c/N)\Delta\tau]$$

where c is the speed of light in free space (*Fig. 2*). The lens is a true time-delay beam-forming mechanism: The values of c and N are constant and the beam scan angle depends only on the time delay, $\Delta\tau$. Providing that $\Delta\tau$ is independent of frequency [as in transverse-electromagnetic (TEM) transmission media] or has only a weak dependency (as in so-called quasi-TEM transmission media such as microstrip), the scan angle does not vary with frequency, as is the case with phased-array antennas. The lens features three focal points, F1, G, and F2, which, when excited, form radiation patterns with peaks at $-\alpha^o$, 0^o, and $+\alpha^o$, respectively. The capabilities of Rotman lenses are well known to many users in the field.

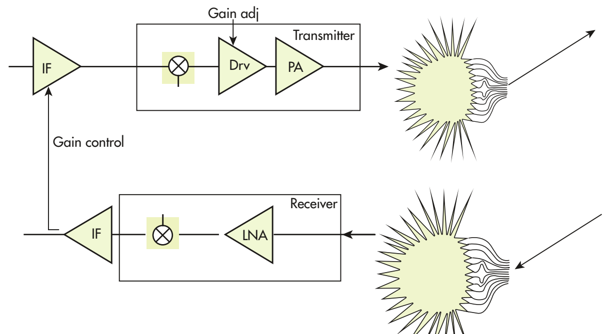


3. The precision machining required in the waveguide structure can be seen in this 94-GHz Rotman lens, which measures only 7 cm long. *(Courtesy of Arralis Ltd.)*

RETRODIRECTIVE OPERATION

A Rotman lens is an ideal retrodirective antenna for a 5G system (*Fig. 3*). When a signal is received from one direction, it can automatically be transmitted back in the same direction without movement of the lens or complicated circuitry; in addition, the response is instant. As an example, imagine a Wi-Fi wireless access point in the corner of a room that receives a transmission from an angle of 30 deg.: t can immediately properly align and transmit back in the same direction.[2-4]

Another example is following a low-earth-orbit (LEO) satellite as it moves across the sky in a period of 10 to 15 min. The connected device on the ground can "lock-on" and stay with the satellite throughout this period. Even more significant is the fact that if the receive antenna is located on a vehicle which is moving and turning, it will constantly maintain alignment with the LEO satellite. When a new satellite appears on the horizon, the signal is automatically acquired again, without noticeable time delay (*Fig. 4*).



4. This basic block diagram shows one channel of a retrodirective system layout using Rotman lenses.

At millimeter-wave frequencies, the lens is best constructed in a waveguide structure to avoid circuit substrate losses. This also requires very careful and precision machining; in particular, the array waveguide paths must be phase matched or the effect upon the phase array will be high sidelobes or poor directivity. The "spillover" areas, as mentioned earlier, either must be absorbed--lined with an RF absorbing material—or, as is common at microwave frequencies, terminated at 50 Ω. Another great advantage of the Rotman lens is that its topology is essentially flat, making it ideal for integration in vehicles and aircraft.

Military organizations such as the U.S. Army Research Laboratories (ARL) have expressed great interest in Rotman lenses for their capability to serve multiple functions, such as radar and communications systems, with a single antenna. In fact, the ARL is currently pursuing key technologies for the integration of low-cost communications and radar systems, so as to create a single system and antenna that is capable of performing multiple functions. The functions will include target acquisition, combat identification, weapons guidance, secure point-to-point communications, and signal interception.

The Rotman lens is a suitable solution for such futuristic, multiple-function military systems. At the same time, the novel antenna is also ideal to meet the needs of the millimeter-wave portions of 5G wireless communications networks, with their high data rates and signal sources on the ground and in the air. It is clear from the performance needs of 5G systems that they will rely heavily on wireless interconnections with LEO satellites, cellular earth stations, and Wi-Fi "hotspots." The Rotman lens is an ideal antenna for sending and receiving signals from those source, whether it is integrated as part of a fixed or mobile 5G wireless communications system. mw

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GET THE ANSWERS to All of Your Wi-Fi Questions

Uncertainty abounds concerning the actual performance of Wi-Fi at 5 and 60 GHz, as maximum theoretical data rates are typically unattainable in real-world environments. A great deal of complexity exists due to the various technical factors involved and the many different Wi-Fi transmission environments. In the white paper "Wi-Fi Data Rates, Channels and Capacity," Qorvo discusses some of the factors that affect Wi-Fi performance and attempts to uncover the actual performance that consumers can expect.

The white paper provides a table that lists theoretical data rates of the different IEEE 802.11 standards. However, those maximum theoretical data rates can only be achieved in the lab under carefully controlled conditions, according to the document. Typical data rates depend on a number of factors, such as signal degradation with distance, modulation rate and forward error correction coding, bandwidth, and several others. The white paper then compares theoretical and advertised data rates with typical data rates, illustrating the differences between them.

Qorvo Inc., 7628 Thorndike Rd., Greensboro, NC 27409; (336) 664-1233; www.qorvo.com

Another topic discussed is the actual throughput per user, which depends on real-world transmission rates and local conditions. Factors to keep in mind include user activity level and distances to the access point, as well as average packet size on the link. Additional factors are the number of users per access point, along with the number of access points and clients on the same channel and within interference range.

Channels and capacity are then examined. Understanding the true capacity of Wi-Fi in a given situation requires taking into account the width of the Wi-Fi channel in use, the number of channels available, and the number of channels in use by other Wi-Fi devices.

The white paper then points out that the IEEE 802.11ax standard promises to deliver a fourfold increase in capacity relative to IEEE 802.11ac. Some of the aspects that will enable this performance to be achieved are detailed. Another major new feature is the provision of a flexible means to allocate channel capacity to specific clients for multi-user transmissions.

LEARN THE DIFFERENCE
Between a Power Divider and a Power Splitter

WHILE A THREE-RESISTOR power divider and a two-resistor power splitter are similar components, they have different characteristics. Hence, each is best suited for different use cases—meaning they are not interchangeable. In the short application note "Differences in Application Between Power Dividers and Power Splitters," Keysight Technologies provides an explanation of both the three-resistor power divider and the two-resistor power splitter before presenting several examples of how they both can be used.

A power divider is a component that equally divides the power of an input signal among multiple output signals. The application note illustrates a three-resistor power divider that consists of three 16 2/3-Ω resistors. Such power dividers are often utilized in test-and-measurement systems. Another point is that this power divider can also function as a power combiner.

The application note also illustrates a two-resistor power splitter that consists of two 50-Ω resistors. This component can be used in leveling loop measurement applications. Utilizing a two-resistor power splitter for source leveling effectively allows for improved source matching.

Next, some applications of both components are presented. For example, a three-resistor power divider can be used to distribute a signal to two different antennas. A power divider can also be used to perform intermodulation-distortion (IMD) measurements. In this scenario, the power divider is actually used as a power combiner. Two signals from two different sources are combined and then applied to a device-under-test (DUT). A spectrum analyzer is used to measure the output of the DUT. Furthermore, diversity gain measurements represent another area of use for power dividers.

Keysight Technologies, 1400 Fountaingrove Pkwy., Santa Rosa, CA 95403-1738; (800) 829-4444; www.keysight.com

The two-resistor power splitter can be used for gain and power testing. The document shows a block diagram of a test setup for an amplifier in which a power splitter is being utilized. As mentioned, leveling or ratioing is another use case for a power splitter. Two block diagrams are presented to illustrate leveling applications. The first one consists of a power splitter and a crystal detector. The second one replaces the crystal detector with a power meter.

CHRIS DeMARTINO | Technical Editor

Get Your Hands Dirty with These VNA Tools

By offering affordable VNAs and a unique set of tools, this company is one that people should know about—especially those in search of a VNA solution.

Recently, I have had the opportunity to get my hands on a couple of the latest vector network analyzers (VNAs) on the market today. In a sense, these new instruments are redefining the VNA, which has traditionally been built in the form of a large box that combines both measurement and display capabilities. While such traditional VNAs are not likely to disappear anytime soon, some of today's VNAs are being built in smaller portable sizes. This smaller size is made possible due to the display functionality being offloaded from the VNA itself to an external PC.

Another company recently provided me with its own PC-controlled VNA as part of a demo kit. That company, MegiQ *(www.megiq.com)*, is one that may be unfamiliar to some. However, MegiQ is a company that certainly deserves to be recognized among today's VNA suppliers. This article presents a closer look at the company's VNA capabilities based on my experience with the demo kit.

VNA DEMO KIT

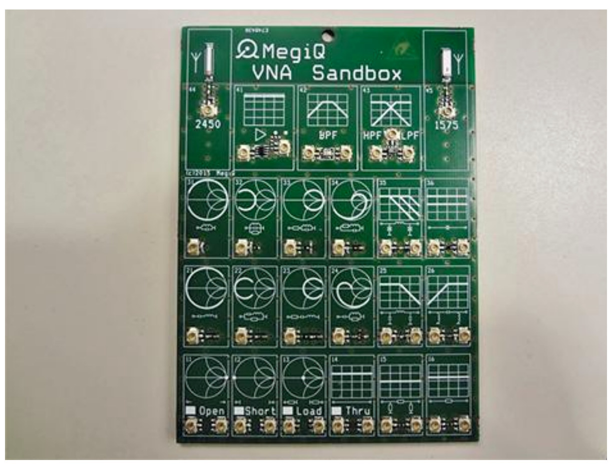
The demo kit included the VNA-0460e, which is a full 2.5-port VNA that covers a frequency range of 400 MHz to 6 GHz *(Fig. 1)*. Since the specifications of the MegiQ VNAs were already reported in a recent article, those won't be discussed in detail here. Readers are encouraged to check out that article, as well as visit MegiQ's website, for more information concerning VNA specifications.

Getting back to the demo kit, it also included the VNA Sandbox along with a number of additional accessories. These accessories included UFL cables, SMA-to-UFL adaptors, and SMA-to-SMA adaptors. Of course, the relevant documentation was also included.

EXPLAINING THE VNA SANDBOX

The VNA Sandbox is actually something very unique that MegiQ offers *(Fig. 2)*. It is essentially a board that contains a number of simple RF circuits. Each of these circuits can be measured with a MegiQ VNA—or any VNA for that matter—via UFL connectors. In addition, every circuit is numbered on the board (more on this later).

1. This is the VNA included in the demo kit. It covers a frequency range of 400 MHz to 6 GHz.



2. This is a photo of the VNA Sandbox, which contains a variety of RF circuits.

Among the circuits included on the VNA Sandbox are several resonant circuits, as well as a few different filters. It also contains antennas, an attenuator, an amplifier, and a varactor-based voltage-controlled lowpass filter. For each circuit, with the exception of the two antennas, the board shows a simple illustration of the response that it produces. MegiQ's website also contains documentation that provides more information concerning the VNA Sandbox circuits.

So what is the purpose of the VNA Sandbox? Essentially, it is intended to help users become better acquainted with performing VNA measurements. Those who are new to using a VNA can learn much by taking advantage of the VNA Sandbox. Proving this point is the Complutense University of Madrid (UCM), as the university is utilizing MegiQ's VNAs and VNA Sandbox to teach students how to perform VNA measurements.

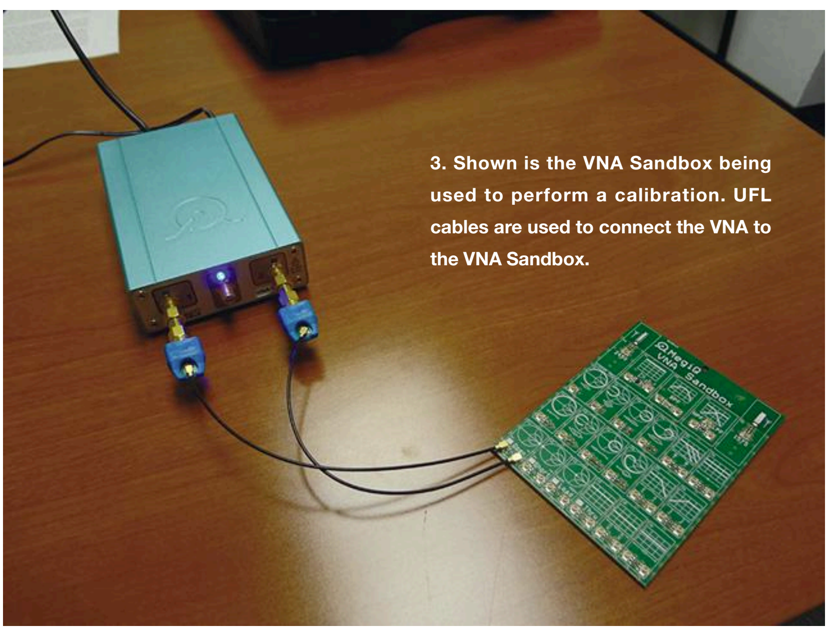
Additionally, the VNA Sandbox includes *Open, Short, Load*, and *Thru* ports to enable users to perform one- or two-port calibrations. Thus, besides containing various RF circuits for measurement purposes, the VNA Sandbox also essentially functions as a calibration kit. *Figure 3* shows a calibration being performed. In *Fig. 3*, the VNA is connected to the *Open* ports of the VNA Sandbox.

One aspect of the VNA Sandbox that should be noted is that it actually contains two *Open, Short*, and *Load* ports each. This enables users to perform calibrations more quickly by simultaneously connecting both *Port 1* and *Port 2* of the VNA to the respective ports for the *Open, Short,* and *Load* calibration steps, as seen in *Fig. 3*.

PUTTING THE SANDBOX TO WORK

Of course, once calibration was performed, the next step was to actually measure some of the circuits on the VNA Sandbox. Performing measurements required using MegiQ's VNA software, which can be downloaded from the company's website.

One nice thing about the software is that it allows users to load built-in measurement files for the circuits on the VNA Sandbox. Loading one of these measurement files basically configures the settings of the VNA software for that specific circuit measurement. Of course, users can also manually configure their own settings.



3. Shown is the VNA Sandbox being used to perform a calibration. UFL cables are used to connect the VNA to the VNA Sandbox.

As an example, let's say that one wants to measure the lowpass filter on the VNA Sandbox, which is designated as circuit 25. That user could load the measurement file titled "VSB 25: CLC LPF." Loading this file subsequently displays four S-parameter graphs. It also displays two Smith charts for the input and output impedances, respectively. *Figure 4* shows the actual measured data of the lowpass filter. Shown are plots for insertion loss and return loss along with two Smith chart displays.

One feature that is included with the VNA-0440e and VNA-0460e models is a built-in bias generator, which was mentioned in the article referenced earlier. To demonstrate this capability, let's take a look at the amplifier on the VNA Sandbox. The amplifier is designated as circuit 41.

One way to measure the gain and return loss of this amplifier is to load the measurement file titled "VSB 41: Amplifier w bias." With this configuration, measurements are performed over a frequency range of 400 MHz to 4 GHz. *Figure 5* shows the measurement results of the amplifier. Four S-parameter plots are shown: gain (S21), reverse isolation (S12), input return loss (S11), and output return loss (S22).

Furthermore, these measurements were performed by utilizing the VNA's aforementioned internal bias generator to power the amplifier. Thus, no external power supply was needed in order to make these measurements. The bias was provided from *Port 2* of the VNA and applied to the amplifier's RF output pin. The bias conditions were set at 5 V and 55 mA (note that this was changed from the measurement file's default conditions of 10 V and 70 mA).

Furthermore, while the amplifier measurements just described were carried out using fixed bias conditions, users also have the option to apply swept-bias conditions. For example, let's take a look at the varactor-based voltage-controlled lowpass filter, which is circuit 35 on the VNA Sandbox. Since this circuit is designed using varactor diodes, its frequency response is dependent on the applied voltage.

By loading the measurement file titled "VSB 35: Varicap LPF Bias-Freq," the bias voltage can be swept from 0 to 3 V in increments of 1 V. Measurements are performed at each bias condition. *Figure 6* shows the insertion loss of the varactor-based lowpass filter at all four bias conditions.

One last point that should be mentioned is that swept-power measurements can also be performed. This capability allows users to measure an amplifier's 1-dB compression (P1dB). In fact, the P1dB of the amplifier on the VNA Sandbox can be measured by loading the measurement file titled "VSB 41: Amplifier 1dB Comp." With this configuration, the power is swept from –15 to +5 dBm.

BEYOND THE VNA SANDBOX: MEASURING SMA-CONNECTORIZED COMPONENTS

The measurements described solely involved the VNA Sandbox, which only contains UFL connectors. To gain a deeper understanding of MegiQ's VNAs, a measurement example of an SMA-connectorized bandpass filter will now be presented. The device-under-test (DUT) in this measurement example is Mini-Circuits' VBFZ-1400-S+ bandpass filter *(Fig. 7)*. This filter has a passband from 1,350 to 1,450 MHz.

4. The measured data of the lowpass filter on the VNA Sandbox is shown here.

5. The amplifier was measured by utilizing the VNA's internal bias generator. Shown is the measured data.

6. Shown is the insertion loss of the varactor-based filter at four different applied voltages thanks to the VNA's swept-bias capability.

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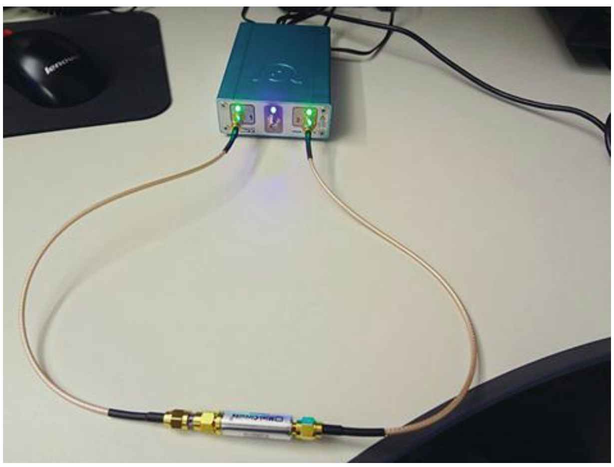
7. Shown is the SMA-connectorized bandpass filter used as the DUT.

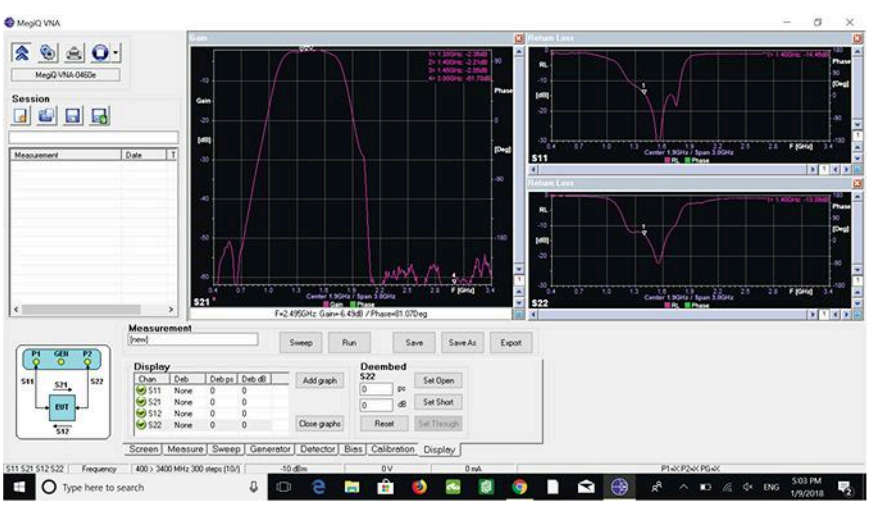
8. This photo shows the SMA calibration kit that was included with the demo kit.



9. This photo shows the filter connected to the VNA.

Of course, calibration was required prior to performing any measurements. To measure an SMA-connectorized component, the proper calibration kit file was imported from a USB stick. Once this step was completed, calibration was performed with the SMA calibration kit over a frequency range of 400 MHz to 3,400 MHz *(Fig. 8)*.

Figure 9 shows the VNA connected to the DUT. *Figure 10* displays plots of measured data. As can be seen, the plots look nice and smooth. In essence, the data agrees with the results one would obtain when performing the same measurements with any currently available VNA. These results therefore demonstrate that MegiQ's VNAs can deliver performance that is comparable to other VNAs on the market today.



10. Shown are the measured insertion loss and return loss of the filter.

CONCLUSION

In summary, MegiQ has proven that it offers quality VNA solutions at an affordable price. The company's VNAs include some features—most notably the built-in bias generator—that are typically only found in more expensive high-end VNAs. In addition, the VNA Sandbox is a good educational tool for anyone who wants to learn more about VNAs. While MegiQ may not be the first name that comes to mind when thinking of VNA suppliers, the company is surely a legitimate one that is worthy of recognition. If you're in the market for a VNA, don't overlook MegiQ. mw

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5G Wireless and the New Imperative for Denser and Faster Multi-Function Devices

Parallel advancement in GaN, MMICs, RF SoCs—and also optical networking technologies—are converging to increase design and cost efficiencies.

The advent of 5G has spurred a rethinking of wireless infrastructure, from semiconductors (*Fig. 1*) to base-station system architectures to network topologies.

At the semiconductor level, the mainstream commercialization of gallium-nitride-on-silicon (GaN-on-Si) has opened the door to improved RF power density, space savings, and energy efficiency. These improvements come at affordable cost structures that are on par with LDMOS at scaled volume production levels, as well as far below GaN-on-silicon-carbide (GaN-on-SiC).

In parallel, the use case for GaN has expanded beyond discrete transistors for high-power RF applications. The economies of scale achieved with GaN's propagation into commercial 4G LTE wireless infrastructure has enabled GaN's migration into the monolithic-microwave-integrated circuit (MMIC) market, where it's helping system designers achieve higher levels of functionality and device integration for next-generation 5G systems.

Meanwhile, the evolution of RF systems-on-a-chip (SoCs) with integrated RF, analog, and digital circuitry has unlocked huge gains in data processing speed across a very wide frequency range, leveraging advanced direct sampling capabilities. At the board level, this eliminates the need for discrete data converters tied to very specific frequency plans, enabling smaller system footprints with digital flexibility and increased input/output (I/O).

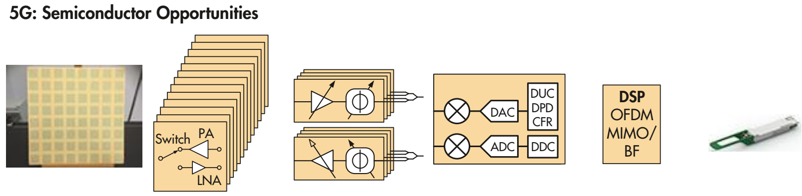
At the network node level, 5G data throughput requirements invite a fresh look at the optical transport technologies tasked with offloading and routing the 5G data deluge. By taking a holistic view of the network from base stations to network fiber optics—from RF to light, if you will—system designers can gain a better understanding of the challenges and opportunities that arise when these technologies intersect.

Here, we will assess the benefits of GaN-on-Si for integrated, multi-function MMICs, as well as the benefits of RF SOCs and advanced optical technology architectures that are affecting the evolution of 5G wireless infrastructure.

INNOVATION IN GAN AND MMICS

The sheer density of massive multiple-input, multiple-output (MIMO) antenna configurations—scaling in excess of 256 transmit and receive elements in a single 5G base station—puts a premium value on available printed-circuit-board (PCB) space, particularly at higher frequencies. To meet this challenge, multi-function MMICs are supplanting discrete integrated circuits (ICs) and single-function MMICs in 5G base-station designs.

5G: Semiconductor Opportunities



	RF Front End	Analog BPF	Transceiver/ Mixed Signal	DSP	Front-Haul
<6 GHz	Multi-technology front end (GaN, SOI, GaAs)	N/A (All Digital BF)	Multi-channel TRx and/or ADC/DAC (CMOS)	Flexible OFDM, MIMO and beamforming DSP (CMOS, FPGA)	Up to 400G front-haul (SiPh,CMOS, Laser)
mmWave	Integrated MMIC/module for high power (GaN, AlGaAs, GaAs)	Phase/amplitude control, signal combining/splitting (SiGe, RF-CMOS)	mmWave TRx and Hi-speed ADC/DAC (SiGe, CMOS)		

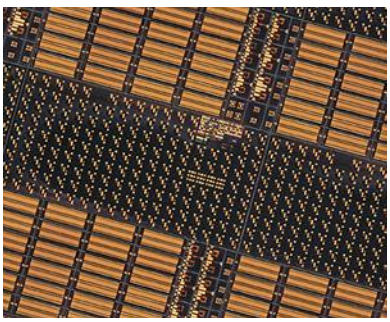
Increased Optical Connectivity. Highly Integrated RF FEM (Front End Modules) = 5G tiles

1. This figure illustrates the different semiconductor technologies that figure to play a role in 5G.

In addition to the benefits in space savings that multi-function integration helps to drive, costs are lowered through a reduction in individual die packaging, design complexity, testing, and assembly labor. Reducing the number of interfaces improves overall mechanical reliability.

Against this backdrop, GaN-on-Si's successful penetration into the commercial semiconductor marketplace comes at a fortuitous time (*Fig. 2*). Its scalability to 8- and 12-in. silicon wafers is enabling cost efficiencies that are well out of reach for GaN-on-SiC, at power densities that can't be achieved with LDMOS—upward of 4× to 6× more power per unit area.

Bridging the gap between these two key attributes, GaN-on-Si is further distinguished by its ability to integrate increased functionality at the silicon level, yielding additional space optimization for ultra-compact MMICs. Its silicon substrate supports homogenous integration of GaN devices and CMOS-based devices on a single chip—a capability that GaN-on-SiC cannot provide due to the inherent process limitations. This opens the door to multi-function, digitally-assisted RF MMICs that can incorporate on-chip digital control and calibration, on-chip power distribution networks, and more.



2. GaN-on-Si technology is already significant in terms of today's commercial market.

RF SOC PROCESSING EFFICIENCY

For 5G base-station infrastructure, the integration benefits and reductions in hardware content enabled by GaN-on-Si-based multi-function MMICs are further complemented by the recent commercial-market emergence of RF SoCs. Integrating multi-Gsample RF data converters for high-speed data processing across a very wide frequency range, RF SoCs streamline the data pipeline and provide a scalable pathway for increasing RF channel-count.

With conventional superheterodyne receiver architectures, signals have to be downconverted to baseband signals, which requires a mixer and additional circuitry. A 2.6-GHz RF signal (4G LTE) would need to be downconverted to the MHz frequency range, where a conventional analog-to-digital converter (ADC) could sample at a lower speed.

In order to place all of the frequency content in the first Nyquist band, you need to sample at 3× the radio frequency. A 2.6-GHz signal would need to be sampled at almost 8 Gsamples/s to achieve this, far outstripping the capability of conventional ADCs sampling at much lower rates—typically 3 Gsamples/s in the 400-MHz frequency range.

A new generation of RF SoCs is overcoming this obstacle, providing the ability to sample signals at up to 56 Gsamples/s. This capability enables direct RF sampling at very high RF frequencies, with the option to down sample. This digital sampling capability eliminates the need for a conventional superheterodyne receiver and discrete data converters, while also eliminating the exciter technology needed for superheterodyne sampling.

RF SoCs can pack a very large number of channels into a very small footprint. Functionally, anywhere from 4 to 16 channels can be fitted into an IC that is approximately 12-×-12 mm instead of requiring multiple circuit cards to do the same thing. This is analogous to the footprint reductions and I/O gains achieved via the evolution from rotary phones to mobile smartphones. And with a defined pathway toward RF CMOS technology at 7-nm spacing, channel density will only continue to grow and power optimization will continue to improve.

Going forward, RF SoCs will enable signals that are increasingly free of distortion—ambiguities and imperfections that previously weren't correctable will be readily correctable. At the system level, here again we see how the benefits of multi-function integration and reduced component count can drive significant space, power, and cost savings for affordable 5G infrastructure.

Also noteworthy, RF SoCs play a key role in the enablement of coherent beamforming, an active phased-array antenna technique used in advanced radar systems that can improve the performance of sub-6-GHz wireless base stations. With coherent beamforming, each transmit and receive element in a massive MIMO array operates in concert with others to dynamically increase transmitted power and receiver sensitivity in the direction of subscribers. This mitigates noise, interference, and reflections from other sources. Leveraging a combination of GaN-on-Si, heterolithic microwave integrated circuits (HMICs), and coherent beamforming technologies, system designers can enable high levels of energy efficiency within the tight size constraints of massive MIMO arrays.

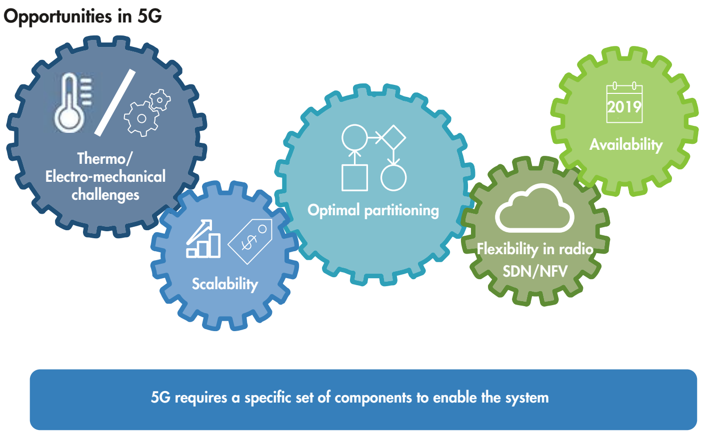
FROM RF TO LIGHT

Wireless network operators and hyperscale data center operators share a common imperative on the pathway to 5G: They need to move data as quickly and cost efficiently as possible. As parallel advancements in RF and optical technologies begin to intersect and integrate, we will gain a clearer perspective of how innovations in one technology domain can affect the evolution of the other.

The faster data processing and throughput speeds achieved at the RF base station are likewise mirrored in the transition from 100G to 400G optical transceiver modules. This is particularly the case in the data center where port density must continue to increase to keep pace with insatiable data demands.

The broader trend toward higher levels of integration and reduced component count is a key factor in the evolution to 400G modules, where the emergence of the single lambda (aka single wavelength) PAM-4 modulation scheme is transforming module architectures. For 100G transceivers, single lambda PAM-4 technology can reduce the number of lasers to one, and eliminates the need for optical multiplexing.

For 400G implementations, only four optical assemblies are needed, representing a major opportunity for data center operators to reduce their cost with an extremely compact and energy-efficient module. This innovation in the hyperscale data center will emanate outward to wireless network nodes in the not-too-distant future.



3. This figure points out some noteworthy factors associated with 5G.

At the semiconductor level, accelerating advancements in silicon photonics technology will transform the composition of next-generation, multi-function MMICs, leveraging established CMOS processes to generate thousands of optical components at a time when on-wafer substrates are leveraging commercial-scale manufacturing techniques. With newfound ability to integrate GaN-based RF devices together with optical devices on a single silicon die—at extremely attractive cost structures—the resulting reduction in interfaces between RF and optical componentry will make it that much easier to push cleaner, faster signals through the network.

In the meantime, continued advancements in GaN-on-Si technology, multi-function MMICs, and RF SoCs will propel the RF/microwave industry toward the realization of more elegant, integrated, and cost effective wireless system infrastructure on the path to 5G connectivity (*Fig. 3*). mw

DON HENRY | Public Safety Program Manager, Comba Telecom
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Reducing Time-Delay Interference in Mission-Critical Situations

While time-delay interference (TDI) is a necessary evil when it comes to public safety communications, its effects can be reduced by utilizing several best practices. This article first explains what TDI is before presenting some approaches that can help to overcome it.

Critical as voice communications are for first responders, time-delay interference (TDI) is a technical effect that could potentially disrupt this vital link. Reducing the effects of TDI should therefore be a priority for all system integrators and design engineers who want to achieve maximum reliability for voice communications systems used in emergencies. In a distributed antenna system (DAS) for in-building wireless networks, there are several ways to reduce TDI to make sure first responders have a clear voice channel in any situation.

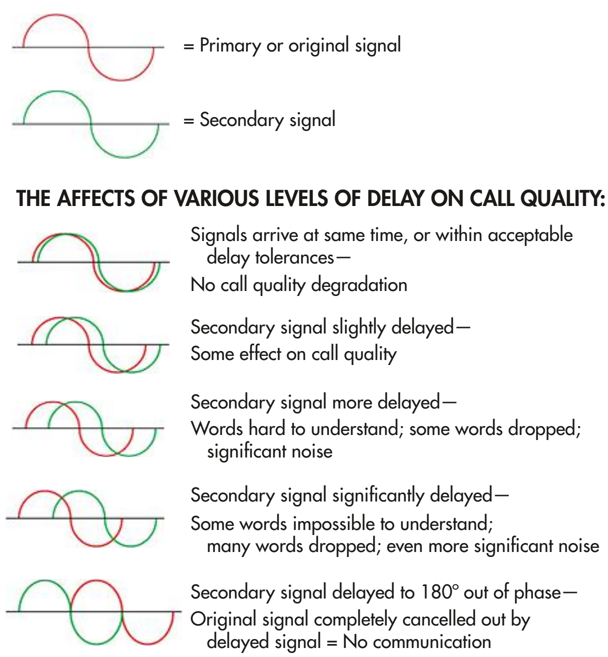
Antenna isolation, system delay, and DAS "dominance" are some of the more important ways of mitigating TDI effects. Those will be explored further, but first, a review of the TDI causes will enable a greater capacity for problem solving.

All public safety systems, whether analog or digital, have the potential to suffer from TDI, which is the byproduct of a radio receiver or DAS antenna receiving multiple "copies" of the same signal at different times. Every simulcast public safety network will introduce time delays. This interference cannot be eliminated completely. However, there are ways that the effects of delay can be controlled.

Figure 1 shows how TDI affects the signal quality. The RF signals are represented here as a waveform.

In approximately 5.37 µs, radio signals travel one mile. In *Fig. 2*, the signal from the donor site one mile away will reach the target building much earlier than the signal from the donor site 15 miles away.

However, there is always a chance that the signal from a donor site located further away will be strong enough to penetrate the building. TDI negatively impacts call quality when a first responder radio inside a building receives and processes both signals because one signal will be greatly delayed.



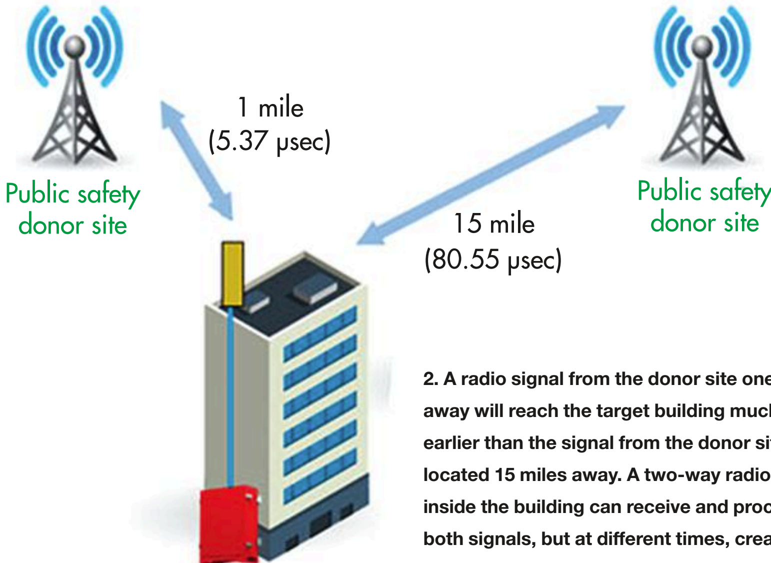
1. This figure illustrates how call quality is impacted by different extents of time delay.

And to make things even worse, if the structure has an in-building coverage enhancement system, (i.e., DAS), there is a strong likelihood that the first responder radio will attempt to receive and process three signals: one from the DAS and one from each of the two donor sites. This compounds the TDI situation and makes call quality even worse.

There are a number of ways to mitigate TDI effects on a public safety DAS system in order to minimize the delay levels to an acceptable level.

Solution providers and DAS installers should offer the following items to ensure public safety call quality:

- Ensure appropriate isolation between the interior service antennas installed in the building, either by adjusting the quantity and physical location of the antennas or by making adjustments in the signal levels delivered to the antennas in what is called "link budgeting." A good design for 700/800 MHz DAS systems calls for isolation of 47 dB; UHF systems call for 42 dB of isolation; and VHF calls for 33 dB of isolation.
- Keep system delay as low as possible. System delay within the DAS system can come from the active equipment. It can also stem from passive components like splitters and couplers, and especially from filters that may be required to accommodate the specific channel requirements. The majority of the 800-MHz networks in use today are P25 Phase I or Phase II. These services require a maximum allowable delay between 15 µs for Phase II to 33 µs for Phase I.



2. A radio signal from the donor site one mile away will reach the target building much earlier than the signal from the donor site located 15 miles away. A two-way radio inside the building can receive and process both signals, but at different times, creating delay and causing quality issues.

Many commercially available bi-directional amplifiers (BDAs) used in public safety DAS systems are available as Class A narrowband devices that can provide delays as low as 15 µs. However, Class B devices provide delay figures as low as 6.5 µs. The solution provider who is deploying BDAs will select the correct model (Class A or B) depending on several criteria, including the desired delay level.

To reduce delay, designers must decide between two possible DAS configurations:

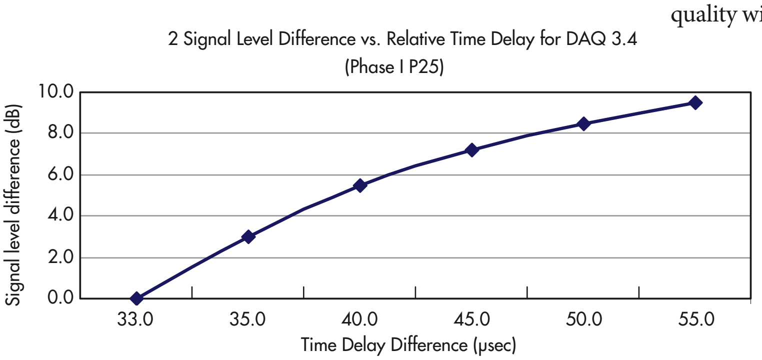
1. One that meets the maximum tolerable delay levels through the methods described above, or;
2. One that asserts "dominance" over the signal from the macro towers that might be penetrating the building.

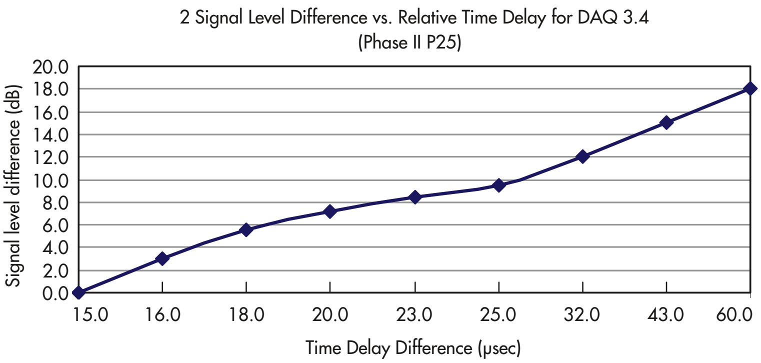
If the best available delay level of the DAS exceeds the maximum figure that can be tolerated, the DAS must be configured for dominance. Increasing the strength of the RF signal that emanates from the DAS antennas allows it to become stronger than the RF signal from the macro tower that is penetrating the building—i.e., the DAS is "dominant" over the penetrating macro signal.

A two-way radio receiver is designed to "reject" the weaker signal. So when a DAS is configured for dominance, the weaker signal from the penetrating tower will not cause TDI problems. An engineer configures this by measuring the strength of the penetrating tower signal, and then calculating how much stronger the signal from the DAS antenna needs to be so that it rejects the weaker one.

Figure 3 indicates the amount of signal level dominance required in order to overcome the TDI issues.

Regardless of what type of in-building DAS systems are in play, the macro network also experiences TDI problems. For example, let's say that if instead of having a building in between the two donor towers (refer to the diagram in Fig. 2), we have a mobile vehicle or handheld radio. The receiver picks up both signals, but one is delayed. Hence, the negative effects on call quality will occur.





3. Time delay calculation charts from "National Public Safety Telecommunications Council (NPSTC)—Best Practices for In-Building Communications—Appendices A through E," November 12, 2007.

To minimize this "open air" TDI problem, the macro network designer and operators will attempt to design a network where the areas covered by the towers do not overlap. To accomplish, they will do one or more of the following:

- Determine the number of tower sites required to provide good coverage without overlapping each other
- Align the donor tower antennas horizontally (left to right) to more precisely align the coverage areas
- Adjust the tower antennas vertically (tilt up or down) to more precisely align the coverage areas
- Select the appropriate size transmitter for the towers (these typically range from 35 to 100 watts of effective radiated power)
- If the macro network is digital, an additional adjustment for overcoming TDI is to intentionally introduce delay on the signal from the closer tower so that it arrives at the same time as the signal from the tower that is farther away.

TDI is inescapable, but knowing how to mitigate its effect can lead to a stable in-building public safety communications DAS system and ensure stable voice communications for first responders. mw

CHRIS DeMARTINO | Technical Editor

In Need of a Real-Time Spectrum Analyzer? Set Your Eyes on This New Solution

Do you know the difference between swept-tuned and real-time spectrum analyzers? This article makes the distinction clear—and previews a recently unveiled RTSA worthy of your attention.

Real-time spectrum analyzers (RTSAs) are important instruments today. But what is an RTSA? And how is it different from a traditional swept-tuned spectrum analyzer? We'll look at some basic differences and then look at a brand-new RTSA now on the market.

"The differences between a swept-tuned spectrum analyzer and an RTSA are fairly fundamental," says Michael Rizzo, general manager at RIGOL Technologies. "A swept-tuned spectrum analyzer basically acquires power measurements across a span—left to right, low to high.

"Since they sweep from left to right, they add a single data point at each measurement step and build an image of what's happening in the spectrum over time," he continues. "That's the way that analyzers have been working for many years, and it's an essential part of an RF toolkit."

However, the current landscape often requires more than what these traditional analyzers can offer. "In today's world," Rizzo adds, "multiple signals are sitting on top of each other in a crowded band and frequencies and pulses are moving really fast (i.e., frequency hopping, amplitude shift technology, etc.). That transient nature of these signals makes them real hard to see with a swept-tuned spectrum analyzer."

Let's now talk about what RTSAs can do. "What RTSAs do is capture data across a fixed span in time," continues Rizzo. "With that data, they then use an FFT process to display the power across the entire span. What happens is that each of those snapshots in time across the real-time bandwidth allows frequency components to be displayed from the same captured data. Since that is happening, you don't miss those transient signals—there is no sweeping. Like a photograph, you catch everything that is happening in that span."

He further adds: "By speeding up the FFTs and overlaying them so that they don't happen sequentially, but rather in a staggered basis, you obtain a gapless view of that time and you don't miss anything between the FFT transactions. Since you're sampling in time, you can also look at changes in frequency over time. This brings a whole new dimension of visualization and debugging to the spectrum analyzer world."

With all of that being said, let's discuss RIGOL's (*www.rigolna.com*) new RSA5000 RTSA (*see photo*). By definition, real-time bandwidth is the subset of the instrument's frequency range in which you are taking FFTs, or snapshots. The RSA5000 is equipped with 25-MHz real-time bandwidth and customers can upgrade that to 40 MHz by purchasing the 40-MHz upgrade option.

This new RTSA is available either as a 3.2-GHz or 6.5-GHz model.

Probability of intercept (POI) is another important parameter, as it describes the shortest duration pulse that the instrument can capture and display for an accurate power measurement. The RSA5000 takes 146,484 FFTs per second, achieving a POI of 7.45 µs.

The targeted applications for the RSA5000 include spectrum monitoring, advanced RF measurements, RF device characterization, and EMI pre-compliance.

For more information, visit *https://www.rigolna.com/real-time/*. mw

Coaxial Terminations Cut PIM to –160 dBc at 1.9 GHz

MODEL LPT10-DM-M01 is a rugged coaxial termination with 7/16 DIN male connector for applications from 0.380 to 6.000 GHz. It handles 10 W average power and as much as 5 kW peak power over that frequency range, with extremely low passive intermodulation (PIM) of –160 dBc at 1.9 GHz. The typical VSWR is 1.15:1 from 0.380 to 0.698 GHz and 1.10:1 from 0.698 to 6.000 GHz. The 50-Ω terminations are designed for use from –55 to +85°C. The terminations are supplied in compact housings measuring 8.5 × 3.0 in.

MECA ELECTRONICS, INC., 459 East Main St., Denville, NJ 07834; (973) 625-0661, (866) 444-6322, *www.aethercomm.com*

End-Launch Connectors Extend to 110 GHz

A NEW LINE of end-launch connectors consists of four models that feature maximum operating frequencies from 40 to 110 GHz and VSWRs as low as 1.10:1. The connectors have a compact profile with a 0.350-in. mounting width and a 0.005-in. launch pin. The outer conductor is made of stainless steel with a gold-plated beryllium-copper center conductor. The reusable connectors are ideally suited for high-speed digital and millimeter-wave circuit and system designs.

FAIRVIEW MICROWAVE, 11792 Fitch, Irvine, CA 92614; (972) 649-6678, *www.fairviewmicrowave.com*

Hybrid Coupler Spans 4 to 44 GHz

MODEL 3040440 is a wideband hybrid coupler with excellent amplitude and phase matching from 4 to 44 GHz. The 3-dB coupler holds insertion loss to less than 3.2 dB across the wide frequency range, with maximum VSWR of 1.65:1 through 30 GHz and 1.90:1 from 30 to 44 GHz. The typical amplitude imbalance is ±1.2 dB while typical phase imbalance is ±12 deg. The isolation between ports is better than 13 dB from 4 to 30 GHz and better than 8 dB from 30 to 44 GHz. The hybrid coupler handles 20 W average power and as much as 3 kW peak power. It is supplied with 2.4-mm female coaxial connectors, measures just 1.99 × 0.80 × 0.42 in., and weighs just 1.5 oz. It is designed for operating temperatures from –54 to +85°C.

KRYTAR, 1288 Anvilwood Ct., Sunnyvale, CA 94089; (408) 734-5999, (877) 734-5999, e-mail: sales@krytar.com, *www.krytar.com*

Wideband MMIC Mixer Converts 10 to 40 GHz

THE MDB-44+ WIDEBAND double-balanced mixer features an RF/LO frequency range of 10 to 40 GHz and wide IF range of DC to 15 GHz. Based on advanced InGaP heterojunction-bipolar-transistor (HBT) technology, the surface-mount MMIC mixer can be used as a frequency upconverter or frequency downconverter. It is well suited for military radar systems and a wide range of satellite and terrestrial communications systems, with low conversion loss (at an IF of 30 MHz) of typically 8.0 dB for RF/LO from 10 to 20 GHz, 8.4 dB for RF/LO from 20 to 30 GHz, and 8.9 dB for RF/LO from 30 to 40 GHz. Designed for typical LO power of +15 dBm, the RoHS-compliant MMIC mixer measures just 3 × 3 × 0.89 mm. In spite of its small size, it achieves high port-to-port isolation, with typical LO-to-RF isolation of 39 dB from 10 to 20 GHz, 37 dB from 20 to 30 GHz, and 30 dB from 30 to 40 GHz; typical LO-to-IF isolation of 33 dB from 10 to 20 GHz, 37 dB from 20 to 30 GHz, and 27 dB from 30 to 40 GHz; and typical RF-to-IF isolation of 24 dB from 10 to 20 GHz, 16 dB from 20 to 30 GHz, and 31 dB from 30 to 40 GHz. The miniature mixer is rated for maximum RF and LO power levels to +21 dBm and operating temperatures from –40 to +85°C.

MINI-CIRCUITS, P. O. Box 350166, Brooklyn, NY11235-003; (718) 934-4500, *www.mini-circuits.com*

Product SPOTLIGHT

The latest product information presented by

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www.minicircuits.com

MMIC Frequency Multiplier Delivers 12.4 to 40.0 GHz

Mini-Circuits' CY2-44+ is a MMIC frequency multiplier capable of a wideband output range from 12.4 to 40.0 GHz. Based on GaAs HBT technology, the frequency doubler works with input signals from 6.2 to 20.0 GHz at input power levels from +12 to +18 dBm and produces output signals with low typical conversion loss of 14 dB. The surface-mount multiplier achieves good fundamental-frequency and harmonic suppression, with typical fundamental-frequency suppression of -26 dBc and typical third-harmonic suppression of -34 dBc. The RoHS-compliant multiplier, which measures just 3 × 3 × 0.89 mm in a 12-lead MCLP package, is suitable for wideband and narrowband applications, including in 5G systems. It is designed for operating temperatures from -40 to +85°C.

USB/Ethernet Peak Power Sensor Turns PCs into 8-GHz Power Meters

Mini-Circuits' PWR-8P-RC is a smart USB/Ethernet power sensor head that turns any personal computer (PC) into a power meter for measurement of peak and average power levels of CW and pulse-modulated signals. It features an input dynamic range of -60 to +20 dBm from 10 to 8000 MHz. The power sensor is supplied with Mini-Circuits' user-friendly GUI software for Windows® with extensive pulse profiling features, and a complete API supporting most programming environments, giving users the same capabilities within their native test software. The smart power sensor is provided with a 6.8-ft.-long USB cable and a female-Type-N-to-male-SMA adapter.

SP4T Solid-State Switch Has USB and I²C Control to 6 GHz

Mini-Circuits' U2C-1SP4T-63H is a low-cost, absorptive single-pole, four-throw (SP4T) switch with USB and I²C control for applications from 2 to 6000 MHz. Typical insertion loss is 3.0 dB or less from 2 to 2500 MHz and 4.2 dB or less from 2500 to 6000 MHz. The switch operates on a typical supply voltage of +5 V dc and has typical switching time of 250 ns. The RoHS-compliant switch is supplied in a rugged metal case measuring 3.75 × 2.50 × 0.60 in. with five female SMA connectors. Easy-to-use GUI control software gives users as easy way to control or automate the switch in Windows operating environments, and a full API allows easy integration and automation with a user's particular software.

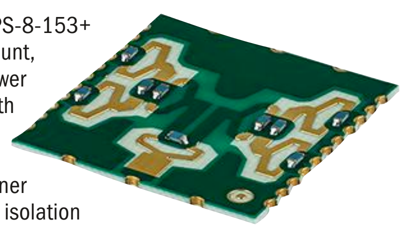
MMIC Directional Coupler Maintains Flat Coupling from 4 to 20 GHz

Mini-Circuits' EDC21-24+ is a 21-dB directional coupler based on GaAs MMIC technology for use from 4 to 20 GHz. It is supplied in a 24-lead MCLP surface-mount package measuring just 4 × 4 mm. It provides 21-dB nominal coupling and maintains coupling flatness within ±2 dB across its full frequency range, with low mainline loss of typically 0.7 dB. The RoHS-compliant, 50-Ω coupler is well suited for satellite-based and terrestrial communications systems and test-and-measurement applications. It has typical directivity of 21 dB from 4 to 8 GHz, 19 dB from 8 to 10 GHz, 16 dB from 10 to 15 GHz, and 14 B from 15 to 20 GHz. It is designed for operating temperatures of -40 to +85°C.

High-Power Rack-Mount Amplifier Boosts 20 to 2700 MHz

Mini-Circuits' HPA-25W-272+ is a rack-mountable, high-power amplifier capable of 25 W typical saturated output power from 20 to 2700 MHz. It is supplied in a rugged, 3U rack-mount enclosure with Type N coaxial input and output connectors. The rugged amplifier features internal cooling, built-in over-temperature protection, and the capability to handle open and short loads while delivering up to 15 W continuous output power. An internal AC power supply enables operation on AC line power from 85 to 264 V ac. The 50-Ω amplifier achieves 50-dB typical gain across its full bandwidth with ±1.5-dB typical gain flatness and 40-dB typical directivity, making it well suited for EMI and component reliability stress testing. The RoHS-compliant amplifier exhibits typical input VSWR of 1.30:1 and typical output VSWR of 2.50:1 and has an operating temperature range of 0 to +50°C.

Surface-Mount Power Splitter/Combiner Spans 6 to 15 GHz



Mini-Circuits' SEPS-8-153+ is a surface-mount, eight-way, 0-deg. power splitter/combiner with wide bandwidth of 6 to 15 GHz. The 50-Ω splitter/combiner features high typical isolation between ports of 25 dB and low insertion loss (above the theoretical eight-way, 9-dB splitting loss) of typically 0.9 dB from 6 to 9 GHz, 1.6 dB from 9.0 to 12.5 GHz, and 3.5 dB from 12.5 to 15.0 GHz. Well suited for wireless communications, radar, and test-and-measurement applications, the RoHS-compliant power splitter/combiner handles power levels as high as 4 W as a splitter. It measures just 0.63 × 0.65 × 0.02 in. and is designed for operating temperatures from -40 to +85°C.

Lowpass Filters Reach 4,000 MHz

AVX HAS ADDED 11 new frequencies to its 0805 high-performance, lowpass LP Series integrated thin-film SMD filters. The RoHS-compliant filters are now available with cutoff frequencies of 700, 750, 780, 942, 1,000, 1,250, 1,800, 1,900, 2,490, 2,900, 3,500, and 4,000 MHz, with low return loss, low passband insertion loss, and sharp rolloff between passband and rejection band. The compact, low-profile 50-Ω filters measure just 2.03 × 1.55 × 0.80 mm with tolerance of ±0.10 mm. They are based on proven multilayer circuit technology and are designed for operating temperatures from –40 to +85°C.

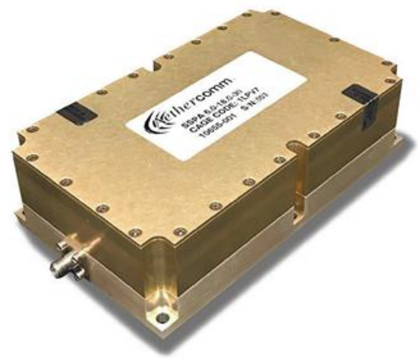
AVX CORP., One AVX Blvd., Fountain Inn, SC 29644; (864) 967-2150, *www.krytar.com*

Compact Synthesizer Tunes from 3 to 6 GHz

THE FCPH300600-10 is a broadband surface-mount frequency synthesizer that tunes from 3000 to 6000 MHz with low jitter and phase noise. It works with a 10-MHz reference frequency and provides at least +3 dBm output power across the frequency tuning range. The typical phase noise is –78 dBc/Hz offset 1 kHz from the carrier and –85 dBc/Hz offset 100 kHz from the carrier. Harmonics are typically –15 dBc while spurious suppression is typically –70 dBc. The RoHS-compliant frequency synthesizer has an operating temperature range of –40 to +85oC.

SYNERGY MICROWAVE CORP., 201 McLean Blvd., Paterson, NJ 07504; (973) 881-8800; *www.synergymwave.com*

GaN-Based Amplifier Powers 6 to 18 GHz



THE SSPA 6.0-18.0-30 GaN-based solid-state amplifier provides at least 20 W output power and 30 W saturated output power from 6 to 18 GHz. It achieves typical small-signal gain of 45 to 55 dB and typical power gain of 40 to 45 dB, with typical power-added efficiency (PAE) of about 15% at the low-end frequencies, about 20% at mid-band, and about 7.6% at the high-end frequencies. A power amplifier (PA) -enabled command signal allows switching speeds of at least 40 μs and as fast as 10 μs. The amplifier is designed for use at operating temperatures from –40 to +70°C.

AETHERCOMM, INC., 3205 Lionshead Ave., Carlsbad, CA 92010; (760) 208-6002, *www.aethercomm.com*

SMT Ceramic Filter Passes 174 MHz

THE AM174B1569 ceramic bandpass filter has a 174-MHz bandwidth and 3-dB bandwidth of 10.7 MHz. It suffers maximum insertion loss of 5 dB across the passband, with VSWR (return loss) of 1.70:1. It provides signal rejection of 40 dB at 27.0 and 33.7 MHz and can handle power levels to 20 W. The 50-Ω filter is assembled by means of surface-mount-technology (SMT) and measures just 25.4 × 12.7 × 6.7 mm. The RoHS-compliant filter is made for operating temperatures from –30 to +70°C.

ANATECH ELECTRONICS, 70 Outwater Ln., Garfield, NJ 07026; (973) 772-4242; *www.anatechelectronics.com*

Pulse Generator Has 10-ns Resolution

THE MODEL 9420 pulse generator allows users to select units with two, four, or eight totally independent output channels, each with its own pulse width and delay time. The instrument features fast timing resolution at 10 ns with jitter of only 400 ps RMS. The generator is equipped with USB, RS-232C, and GPIB instrument interfaces for connection to an external computer. The units also come with fast programming and a range of modes which includes single, continuous, burst, duty cycle or externally controlled operation. Programmed settings can be stored in one of 12 memory locations. P&A: $2,500 (two-channel unit) and up; stock to seven days.

QUANTUM COMPOSERS, INC., 212 Discovery Dr., Bozeman, MT 59718; (406) 582-0227; e-mail: sales@quantumcomposers.com, *www.quantumcomposers.com*

Service Provides Safe Storage for Components

LONG TERM STORAGE SOLUTIONS (LTS²) is an opportunity for manufacturers and users of electronic components to provide long-term storage of electronic components without risk of degradation or deterioration of performance. The storage facility, in Zwolle, The Netherlands, features a safe, secure quarantined area that is compliant to international standards for MSD and LTS component storage. The facility employs a number of the latest technologies to ensure temperature and humidity control with fully traceable logging capability so that customers have real-time access to the status of their stock. The facility also offers a variety of testing services, including for diffusion, moisture absorption, dewetting, and whisker formation.

TOTECH EUROPE B.V., Paxtonstraat 11, 8013 RP, Zwolle, The Netherlands; +31 38 2031051, e-mail: info@superdry-totech.com, *www.superdry-totech.com*

Power Amplifier Boosts Small Cells to 5.9 GHz

MODEL QPA9501 is a solid-state power amplifier well suited for LTE-U/LAA wireless infrastructure applications from 5.1 to 5.9 GHz. The three-stage amplifier achieves 32-dB gain and +32 dBm output power and has a low adjacent-channel level ratio (ACLR) of –47 dBc at +23 dBm output power. It draws 350 mA current from a +5-V dc supply and is supplied in a compact housing measuring 5 × 5 mm. It offers performance well suited to low-power wireless systems, including small cells and Wi-Fi access point.

RFMW LTS., Stocking Distributor for QorvoLTD, 188 Martinvale Ln., San Jose, CA 95119; (408) 414-1450; e-mail: info@rfmw.com, *www.rfmw.com*

Amplifier Drives 1 kW from 1 to 30 MHz

THE SKU 2203 solid-state power amplifier delivers 1000 W saturated output power from 1 to 30 MHz, with performance well suited for electromagnetic-interference (EMI) and radio-frequency-interference (RFI) test systems. It is capable of 800 W output power at 1-dB gain compression, and provides 60-dB gain at 1-dB gain compression. For its enormous output power, the amplifier also achieves a healthy noise figure of 10 dB for accurate testing. The rack-mountable power amplifier is based on silicon LDMOS device technology and is designed to operate from a three-phase 208-V ac line. It includes built-in control and monitoring circuitry and forced-air cooling for excellent long-term reliability.

EMPOWER RF SYSTEMS, INC., 316 W. Florence Ave., Inglewood, CA 90301; (310) 412-8100, e-mail: sales@empowerrf.com, *www.empowerrf.com*

Electromechanical Switches Control 900 W to 26.5 GHz

A NEW LINE of high-power components features a total of 44 electromechanical switches capable of handling power levels to 900 W over a total frequency range of DC to 26.5 GHz. The switches, which are available in +12 and +28 V dc versions, exhibit insertion loss of 0.15 dB with as much as 90-dB isolation between switched ports. They are RoHS and REACH compliant and meet the environmental requirements of MIL-STD-202 for military applications. The rugged electromechanical switches, which have an operating temperature range of -20 to +70°C, are available in a variety of configurations, including single-pole, double-throw (SPDT), single-pole, three-throw (SP3T), single-pole, four-throw (SP4T), and single-pole, six-throw (SP6T) versions, with latching, failsafe, or normally open actuators. They include transistor-transistor-logic (TTL) control and are supplied with SMA or Type N coaxial connectors.

PASTERNACK ENTERPRISES, 17792 Fitch, Irvine, CA 92614; (978) 682-6936, *www.pasternack.com*

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