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INTERCEPT

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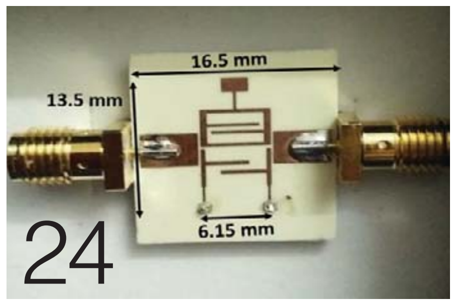

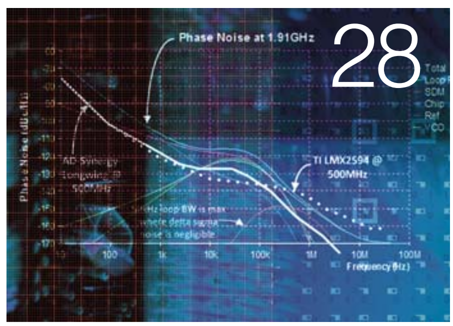

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defense electronics

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Editorial

After nearly five years with the magazine, it's now time to move on to the next chapter.

To the *Microwaves & RF* audience, I start by bringing you the news that this column will be my final one, as I'm leaving the magazine after four-and-a-half years. And while I'm truly grateful for the experience I've had here, I'm also looking forward to what lies ahead.

When I first embarked upon this job back in May 2015, I had much enthusiasm for what I was getting into. And I was not disappointed, as this position has been everything I could ask for. From working in New York City to seeing the industry from a much different perspective and a whole lot more, this job certainly made a lasting impact on me.

However, the time has now come to close this chapter and move on to the next one. And the next step for me is a new position with Modelithics *(www.modelithics.com)*, a company that has intrigued me for some time. So, while it's bittersweet in a sense to be leaving *Microwaves & RF*, I'm looking forward to the opportunity to work with the Modelithics crew.

Before leaving, I would like to take this opportunity to thank some of the people I've worked with during my time here. First, while she has since moved on, I have to thank Nancy Friedrich, who gave me the opportunity to work for the magazine in the first place. I also have to say thank you to Mr. *Microwaves & RF* himself, Jack Browne, for all of his support.

I would also like to thank my other colleagues—people like Roger Engelke, Jeremy Cohen, Tony Vitolo, Jocelyn Hartzog, and Vicki McCarty, just to name a few. On top of that, I want to thank the many people from the different companies I've had an opportunity to work with during my time here. Of course, I cannot name everyone, but I really appreciate all of the support I received.

I'm also hopeful that you, the reader, enjoyed the work I did. And I hope that you continue to enjoy *Microwaves & RF* for some time to come. And with that, I'll call it a wrap. But before I do, as we end the year, I would just like to wish everyone a Merry Christmas and a Happy New Year! Until next time… mw

CHRIS DeMARTINO | Editor
chris.demartino@informa.com

Microwaves&RF **DECEMBER 2019**

EDITORIAL

GROUP CONTENT DIRECTOR: **KAREN FIELD** karen.field@informa.com
SENIOR CONTENT DIRECTOR: **BILL WONG** bill.wong@informa.com
EDITOR: **CHRIS DeMARTINO** chris.demartino@informa.com
SENIOR STAFF WRITER: **JAMES MORRA** james.morra@informa.com
TECHNICAL EDITOR: **JACK BROWNE** jack.browne@informa.com
ASSOCIATE EDITOR/COMMUNITY MANAGER: **ROGER ENGELKE** roger.engelke@informa.com

ART DEPARTMENT

GROUP DESIGN DIRECTOR: **ANTHONY VITOLO** tony.vitolo@informa.com
CONTENT DESIGN SPECIALIST: **JOCELYN HARTZOG** jocelyn.hartzog@informa.com
CONTENT & DESIGN PRODUCTION MANAGER: **JULIE JANTZER-WARD** julie.jantzer-ward@informa.com

PRODUCTION

GROUP PRODUCTION MANAGER: **GREG ARAUJO** greg.araujo@informa.com
PRODUCTION MANAGER: **VICKI McCARTY** vicki.mccarty@informa.com

AUDIENCE MARKETING

USER MARKETING MANAGER: **DEBBIE BRADY** debbie.brady@informa.com

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SALES & MARKETING

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REGIONAL SALES REPRESENTATIVES:
AZ, NM, TX: **GREGORY MONTGOMERY** **T** | 480.254.5540 gregory.montgomery@informa.com

AK, NORTHERN CA, OR, WA, WESTERN CANADA: **STUART BOWEN** **T** | 425.681.4395 stuart.bowen@informa.com

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ELIZABETH ELDRIDGE **T** | 917.789.3012 elizabeth.eldridge@informa.com

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JAMES RHOADES-BROWN **T** | +011 44 1932 564999 **M** | +011 44 1932 564998 james.rhoadesbrown@husonmedia.co.uk

ITALY: **DIEGO CASIRAGHI** diego@casiraghi-adv.com

PAN-ASIA: **HELEN LAI** **T** | 886 2-2727 7799 helen@twoway-com.com

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mary.ralicki@informa.com

DIGITAL

GROUP DIGITAL DIRECTOR: **RYAN MALEC** ryan.malec@informa.com

DESIGN ENGINEERING & SOURCING GROUP

GROUP CONTENT DIRECTOR: **KAREN FIELD** karen.field@informa.com
VP OF MARKETING: **JACQUIE NIEMIEC** jacquie.niemiec@informa.com

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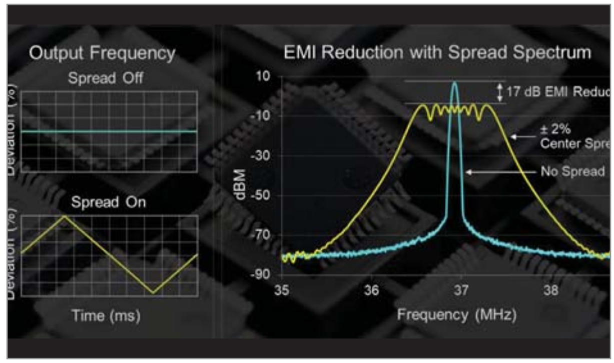

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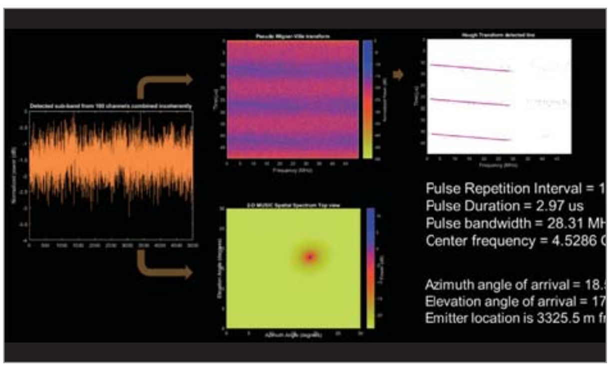

Train Deep-Learning Networks with Synthesized Radar and Comms Signals

This "Algorithms to Antenna" blog shows how you can use learning techniques in cognitive radar, software-defined radio, and efficient spectrum-management applications to effectively identify modulation schemes.

https://www.mwrf.com/systems/algorithms-antenna-train-deep-learning-networks-synthesized-radar-and-comms-signals

Editor's Choice: Making IoT Connections

If it's IoT, it's probably wireless. What are the connectivity solutions making the most "waves" these days?

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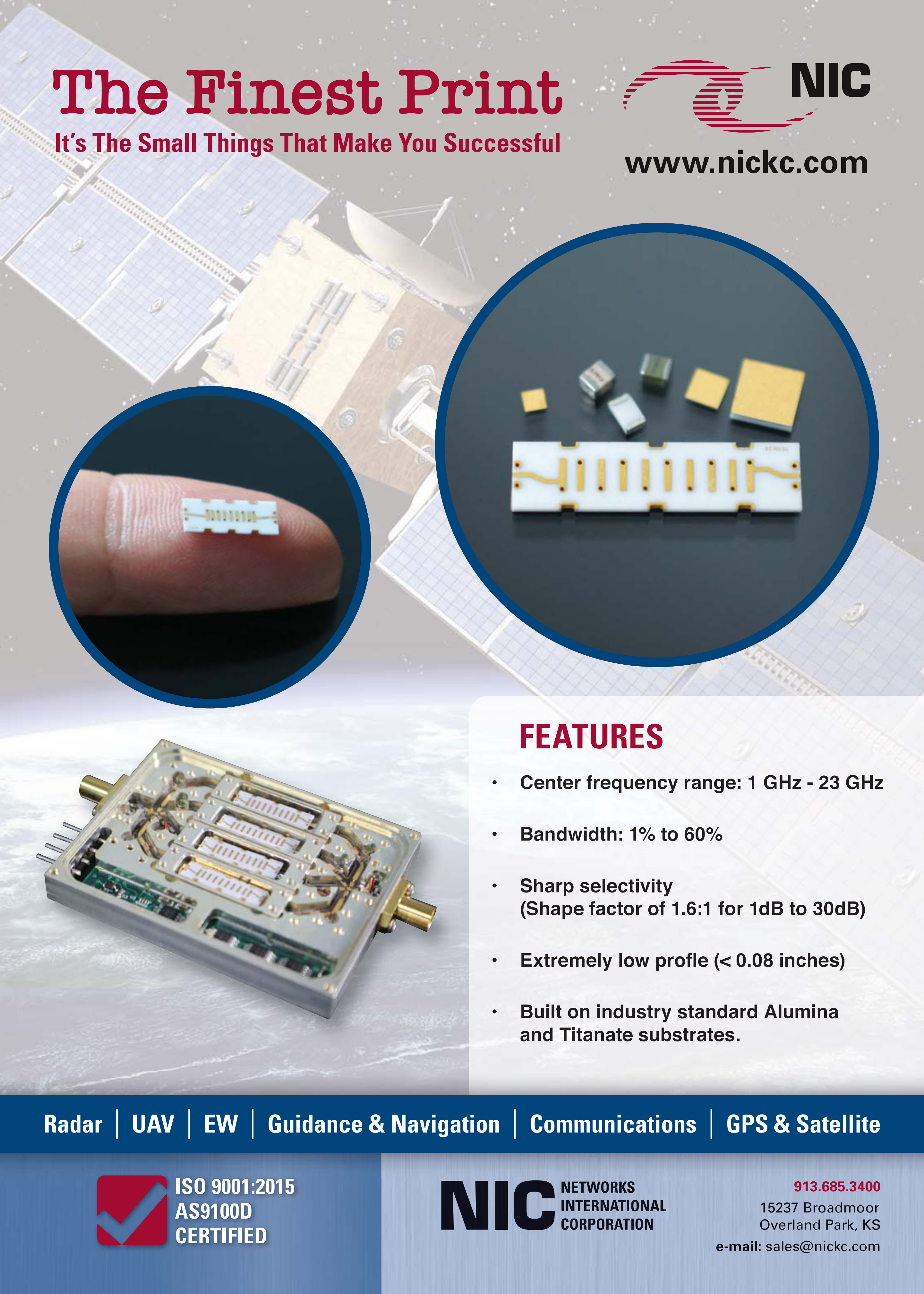

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News

Hermetic TO Packages and Headers MEET LATEST CHALLENGES

Electronic Products (EPI) (*www.elecprodinc.com*) recently announced advanced capabilities to produce hi-rel transistor-outline, or TO, packages and headers. Originally developed by the semiconductor and microelectronics industry in the 1950s, the TO design for packages and headers was created to support the early development of hermetic devices in a common suite of easy-to-implement package outlines.

While there are plastic versions of TO packages, EPI's focus has been to improve on standardized TO packages and headers made of metals. The goal is that these will help meet the most rigorous hermetic standards and screening requirements of today's hi-rel semiconductor devices and components.

The basic TO or "metal can" package consists of a metal base with leads exiting through a glass seal. The glass-sealing process is among the many areas in which EPI has made innovations, specifically in both compression-seal and matched-seal technology. EPI's matched seals typically use coefficient of thermal expansion (CTE) matched ASTM-F15 alloy (Kovar) and CTE matched glass compositions.

The company's highest-performing compression seals employ plain carbon steel 1010 and ASTM-F30 (Alloy 52) with higher CTE to compress the glass upon cooling during the fusing process of the TO package or header. After device assembly in the package, the customer applies a metal lid that's resistance-welded with precision to the metal base to form a superior hermetic seal.

The TO design was developed to support the initiative in 1944 put forth by the Joint Electron Device Engineering Council (JEDEC) (*www.jedec.org*). JEDEC initially functioned within the engineering department of the Electronic Industries Association (EIA); its primary activity was to develop and assign part numbers to devices. Over the next 50 years, JEDEC's work expanded into developing test methods and product standards that proved vital to the development of the semiconductor industry. In addition to several standardized TO package outlines and header designs, other landmark standards initiated by JEDEC committees include:

- The electrostatic discharge (ESD) symbol used worldwide on semiconductor devices.
- Specifications for computer memory, ranging from dynamic RAM chips and memory modules to double-data-rate (DDR) synchronous DRAM and flash components.
- Development and publication of a manual of common terms and definitions for the semiconductor industry.
- Standards, publications, and educational events addressing the migration to lead-free manufacturing processes. One of the most popular standards in JEDEC history—J-STD-020—resulted from this work.

TO packages and headers are in use today in all areas of microelectronic applications, on both the transmit and receive side of a transceiver system. They're also proven in high-speed data

transfer, infrared, and other optoelectronic applications. EPI's TO packages and headers are qualified to the rigorous JESD9C standard that's used in conjunction with the most up-to-date test methods described by MIL-STD 883.

Microelectromechanical systems (MEMS) packaging represent a new area of microelectronic packaging applications for the TO package. EPI is currently developing advanced solutions for this packaging option. MEMS systems, which now enable optical signals to be switched using a range of small mobile mirrors, are becoming increasingly accepted in high-volume applications like LCD projectors.

EPI specializes in the design and manufacture of both legacy and custom-engineered TO packages and headers used in a variety of high-performance applications, such as RF/microwave/wireless, optoelectronics, photonics, and power-semiconductor applications. In addition to traditional "TO-cans," optional styles include stamped, coined, cold-headed, drawn, machined, multi-pin headers, and more.

Visit: *https://www.elecprodinc.com/to-packages-and-header.* ■

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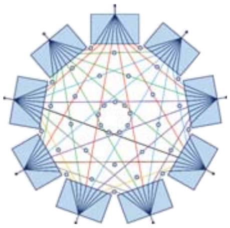

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MINI-CIRCUITS EXPANDS Amplifier Design Capability

MINI-CIRCUITS *(WWW.MINICIRCUITS.COM)* has expanded its amplifier design capabilities with the addition of a new design engineering group dedicated to developing high-power amplifiers up to and beyond 1 kW at frequencies through 8 GHz (*see figure*). The new team, which will be based in a new corporate design center in Lincoln, R.I., with a satellite office at the Novio Tech Campus in Nijmegen, Netherlands, brings over 100 years of combined experience designing and developing RF amplifiers and power products.

Mini-Circuits currently offers over 75 standard power-amplifier (PA) models from 2 to 100 W covering bandwidths up to 18 GHz. The expansion will build on the popularity of the company's existing PA line and respond to industry demand with a wide range of new products and capabilities.

"We're very excited to welcome this talented team to the Mini-Circuits family," said Steven Scheinkopf, Mini-Circuits VP of technical marketing. "This expansion continues our long-term focus and success in the amplifier space. The knowledge and experience of the Rhode Island group will bring our offering to the next level both in terms of selection and truly leading-edge technology."

The Lincoln team will be led by product line manager, Korne Vennema. "We're very fortunate to be part of a company with such a depth in RF components and solutions," he said. "We can't wait to help further expand Mini-Circuits' reliable high-power-amplifier product offering."

Before joining Mini-Circuits, Vennema held various design engineering, application support, and management roles at Phillips, NXP Semiconductor, and MACOM.

The Lincoln and Nijmegen offices are now among Mini-Circuits' 14 design, manufacturing, and sales locations that span nine countries.■

The new design engineering team is focused on developing high-power amplifiers.

QUALCOMM FORECASTS 200 Million 5G Phones in 2020

QUALCOMM SHARES HAVE surged more than 10% since the world's largest smartphone chip vendor said in early November that overall sales could start to recover in the first quarter of 2020 as consumers move en masse to 5G smartphones and its patent licensing business rebounds from a legal spat with Apple. Qualcomm said it expects 175 million to 225 million 5G smartphones to be shipped in 2020, signaling a strong year ahead.

The company sells more smartphone chips than any other vendor in the world. But most of its profit is made from licensing patents that are central to 3G, 4G, and 5G technology and reaping the royalties from handset makers. The licensing business came to $1.22 billion in the fourth quarter of 2019, up 4% from the fourth quarter a year ago, bolstered by the return of royalties due on sales of Apple's iPhones and other devices.

Qualcomm resolved its dispute with Apple in the second quarter, and Apple agreed to pay out $4.7 billion in the settlement. The company has also entered long-term patent licensing and chip supply deals with Qualcomm, opening the door for Apple to use Qualcomm's modems in its future iPhones, including 5G devices. Qualcomm said its licensing business would be in the range of $1.3 billion to $1.5 billion in the first quarter, up from $1 billion roughly one year ago.

"We're pleased with the progress we've made over the course of 2019 and believe the business is very well positioned for sustained long term growth," said Steve Mollenkopf, Qualcomm's CEO, on a conference call with Wall street analysts on Wednesday. The company said sales in the first fiscal quarter would be in the range of $4.4 billion to $5.2 billion, even though global shipments of its chips will be 145 million to 165 million units, down 11% to 22% year-over-year.

Qualcomm is looking to take advantage of its early lead in 5G technology, which it believes will breathe new life into the smartphone market, which has stagnated as consumers hold onto handsets longer. More than 230 smartphones or other devices are on the market or in development with its 5G modem chips, up from 150 over the last quarter. Alex Rogers, who leads the licensing business, said the company has hammered out more than 75 agreements for 5G. ■

CHRIS DeMARTINO | Editor

Digital Transceiver is READY FOR BATTLE

Suitable for a wide range of applications, this new transceiver features the latest commercial technology and offers advantages such as modularity.

Developing high-performance solutions for defense applications is the focal point of Mercury Systems (*www.mrcy.com*), which offers products that range from mixed-signal-processing solutions to RF/microwave components and much more. And the company isn't showing signs of slowing down, demonstrated in part by the recent introduction of the DCM6112 digital transceiver (*see figure*).

According to the company, this new product is "optimized to provide the best balance of low latency and wide bandwidth for critical electronic-warfare (EW) applications." The team in Mercury's Huntsville, Ala. facility is responsible for the DCM6112's development and manufacturing.

What does the DCM6112 digital transceiver bring to the table? Mario LaMarche, product marketing manager at Mercury Systems, says, "The term 'digital transceiver' in this case represents a digitization front end that takes an analog signal and then digitizes that signal. The DCM6112 then utilizes integrated FPGA devices to provide low-latency digital signal processing.

The DCM6112 is an open-architecture-based digital transceiver that features four analog-to-digital converter (ADC) channels as well as four digital-to-analog converter (DAC) channels.

> "Some of the semiconductor devices that are integral to the performance of the DCM6112 represent the latest commercial digitization technology. We have methods of taking these commercial devices and packaging them into a subsystem so that they can be used in a defense application."

The signal can then be converted back to analog and transmitted. This functionality allows the user to perform real-time processing to mitigate electronic threats."

The flexibility to support a wide range of applications is one of the DCM6112's prime benefits. LaMarche explains, "Generally, for these digital transceivers, we're not developing the application-specific algorithms for the FPGA blocks. Instead, we're leaving it very open so that the transceiver can be used in a wide range of applications. However, some of the design characteristics of the DCM6112 make it particularly well-suited for applications that require real-time, low-latency processing."

LEVERAGING COMMERCIAL TECHNOLOGY INNOVATIONS

While Mercury Systems is known as a provider of solutions for defense applications, the company is implementing a business approach that involves leveraging commercial technology innovations. LaMarche adds, "Company-wide, Mercury has developed a business model that leverages the significant technology investments of commercial industries. Over the recent decades, we have been witnessing an increasing level of commercial technology investment—especially around semiconductor devices. Leveraging this high commercial technology growth rate requires the ability to add mission-specific customization and ruggedization to these devices."

How does this practice of leveraging commercial technology specifically apply to the DCM6112? LaMarche points out, "Some of the semiconductor devices that are integral to the performance of the DCM6112 represent the latest commercial digitization technology. We have methods of taking these commercial devices and packaging them into a subsystem so that they can be used in a defense application. And because of the rapid pace of technology improvement in the commercial space, we use a modular architecture that allows us to take this commercial innovation and very rapidly deploy it to defense applications."

Mercury Systems is now accepting orders for the DCM6112 digital transceiver.

EASY INTEGRATION PLUS MODULARITY

The DCM6112 is compliant to the OpenVPX standard, which, according to LaMarche, "allows customers to use it in their systems with very minimal integration time by avoiding the need for custom-designed form factors. This allows for rapid upgrades as new technology becomes available."

One attribute already mentioned is the DCM6112's modular design. Such modularity enables Mercury to better prepare for next-generation technology. "The modular design allows us to make upgrades faster as next-generation technology becomes available," says LaMarche. "The digitization chipsets are located on a mezzanine card that sits on the FPGA base module. That allows us to make incremental improvements by simply pulling off one mezzanine card and putting on a new one. Through this modular design and an open-architecture framework, we can very quickly take the next generation of commercial technology and apply it to the defense industry."

In terms of its functionality, the DCM6112 features four 12-bit analog-to-digital converter (ADC) channels along with four 12-bit digital-to-analog converter (DAC) channels. These ADC and DAC chipsets are located on a mezzanine card, as mentioned.

LaMarche explains that two different modes of operation are possible. "One option involves taking a signal directly from an antenna, digitizing that signal, and performing the processing," he says. "Another option is to take an intermediate-frequency (IF) signal from the output of a microwave transceiver and process that IF signal. Once you digitize this analog signal, the very low latency of the digitization chipset enables us to quickly take that digital signal and route it to the FPGA processing blocks. After real-time processing is applied, the signal can be converted back to analog and transmitted."

Regarding the process that's enabled by the DCM6112, LaMarche explains, "As new threats emerge across the electromagnetic spectrum, they can be received, digitized, and processed with application-specific digital-signal-processing (DSP) techniques. The signal can then be retransmitted to mitigate the electronic threat."

One additional benefit of the transceiver lies in Mercury's coherency technology. With this feature, the multiple channels on the board (i.e., mezzanine card) can be run coherently so that they are aligned with the output.

LaMarche notes that this coherency technology is also scalable. "The board supports the hardware to scale it with multiple boards, so you can scale up the number of coherent channels," he says. "This is important for applications such as direction finding, in which you not only need to mitigate these threats, but you also need to know the direction they're coming from. By having multiple highly scalable coherent channels, a customer can very quickly take advantage of the open architecture and the scalable channel counts to develop a system that can not only mitigate electronic threats, but also locate them."

Mercury Systems is now accepting orders for the DCM6112 digital transceiver, available in both standard configurations and custom variants for specific program needs. For more information, visit *www.mrcy.com/dcm6112.* mw

AHMED F. DAW | Assistant Professor, Electrical Systems Engineering Department, MSA University, Cairo, Egypt
PETER A. FAWZEY | Researcher, Electrical Systems Engineering Department, MSA University
MARIAN N. ADLY | Researcher, Electrical Systems Engineering Department, MSA University

Quad-Band Resonator Depends on CRLH/D-CRLH Structures

The design of this novel multi-band resonator allows for multiple passbands while keeping size to a minimum.

This article presents the design and implementation of a compact quad-band bandpass filter based on coupling between via-free dual-composite right-/left-handed (D-CRLH) and composite right-/left-handed (CRLH) microstrip structures. The filter can be used for multiband wireless applications like WiMAX and WLAN, as well as other high-frequency applications. Its topology results in four bands with highly selective, sharp bandpass responses.

A design is introduced to realize a quad-band resonator. Also presented are the equivalent circuit model, an analytical study, and simulation and fabrication measurement results.

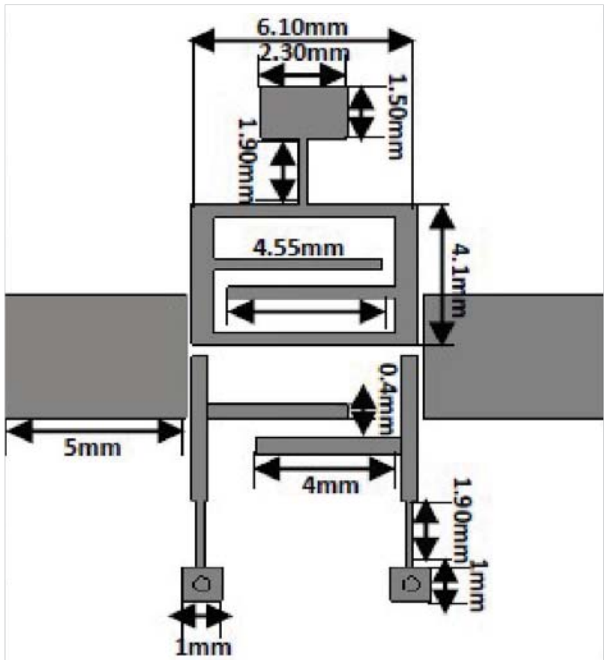
INTRODUCTION

The electromagnetic (EM) propagation phenomena in one direction through an effectively homogeneous material can essentially be modeled by a one-dimensional transmission-line.[1] However, in practice, such a pure left-handed (PLH) transmission line is impossible to manufacture. A more practical model is the CRLH,[1] or its dual-version counterpart, the D-CRLH.[2]

A CRLH or D-CRLH transmission line may be obtained by chaining several unit cells. These types of artificial lines exhibit dual-band behavior. Consequently, dual-band microwave devices can be created with CRLH and D-CRLH structures.[9-12]

Today, one of the main goals when designing a device is to reduce the dimensions as much as possible. Many compact and multiband filters have been suggested based on metamaterials—metamaterial-based filters are considered novel devices.[3-8] Coupled metamaterial resonator filters are used to create compact bandpass filters.[6-8]

The design of the microwave resonator is significant. Resonators are widely used as elements for high-quality oscillators in satellite military communication systems, as well as multiband antennas for wireless applications.[13]

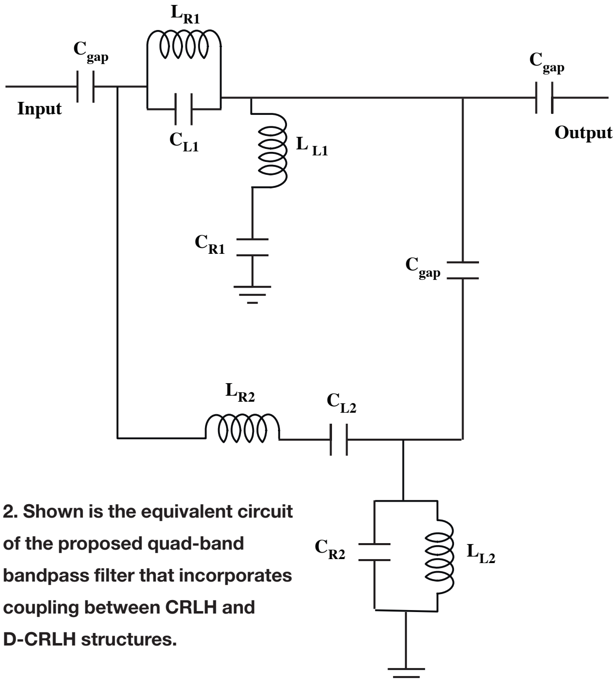


1. This is the configuration for the novel quad-frequency resonator based on metamaterial transmission lines.

With the proposed structure, it's possible to have four passbands. The resonator, which measures just 16.5 × 16.5 mm, delivers the performance at multiple frequencies and the compact size required for many modern communication circuit designs.

THEORY AND DESIGN

The multiple-band resonator is fabricated on standard commercial circuit material *(Fig. 1)*. It consists of a CRLH unit cell coupled with a D-CRLH unit cell. A coupled gap transmission-line resonator is based on coupling between the D-CRLH and CRLH transmission lines. The CRLH transmission line is



2. Shown is the equivalent circuit of the proposed quad-band bandpass filter that incorporates coupling between CRLH and D-CRLH structures.

responsible for low frequencies, while the D-CRLH transmission line is associated with high frequencies. The resonator is designed using a Rogers *(www.rogerscorp.com)* RO4350B substrate with a dielectric constant of 3.48 and a thickness of 1.524 mm. The total dimensions are 16.5 × 16.5 mm.

Figure 2 shows the equivalent circuit of the proposed quad-band bandpass filter that features coupling between the CRLH and D-CRLH structures. The two lower-frequency bands are produced from the CRLH transmission line, while the two higher-frequency bands come from the D-CRLH transmission line. The CRLH structure has a highpass-filter profile with two possible passbands (left-handed at lower frequencies and right-handed at higher frequencies).

The D-CRLH transmission line has a lowpass-filter profile, which also allows for two possible passbands (right-handed at lower frequencies and left-handed at higher frequencies). However, with the D-CRLH transmission line, nonlinear propagation phase is opposed. The D-CRLH transmission line has gained more interest than the CRLH transmission line because it's simpler to realize thanks to via-free requirements for microstrip configuration.

INDUCTOR AND CAPACITOR VALUES

The four resonant frequencies are 3.9, 4.6, 6.2, and 7.1 GHz. The relationship between frequencies and the inductors/capacitors are as follows:

$$F_1 = \frac{1}{2\pi\sqrt{C_{L1}L_{R1}}} \quad (1)$$

$$F_2 = \frac{1}{2\pi\sqrt{C_{R1}L_{L1}}} \quad (2)$$

$$F_3 = \frac{1}{2\pi\sqrt{C_{L2}L_{R2}}} \quad (3)$$

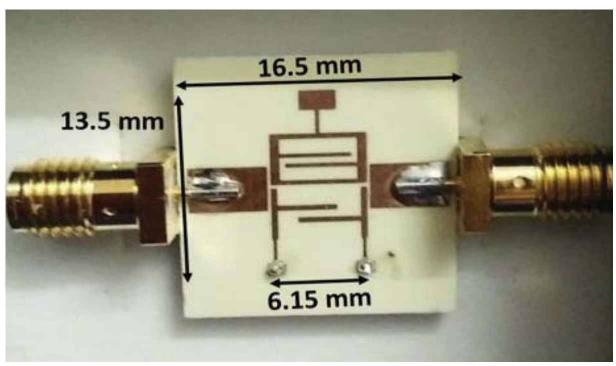
$$F_4 = \frac{1}{2\pi\sqrt{C_{R2}L_{L2}}} \quad (4)$$

The coupled capacitor is realized using an air gap, C_{gap}, that's equal to 0.014 pF. The remaining values are:

C_{L1} = 1.2 pF
L_{R1} = 1.387 nH
C_{R1} = 0.935 pF
L_{L1} = 1.284 nH
C_{L2} = 0.482 pF
L_{R2} = 1.367 nH
C_{R2} = 0.325 pF
L_{L2} = 1.546 nH

COMPACT RESONATOR FABRICATION

Figure 3 shows the metamaterial-based quad-band resonator constructed with a CRLH cell coupled with a D-CRLH cell. The resonator is fabricated on commercial printed-circuit-board (PCB) material from Rogers with a dielectric constant of 3.48 and a thickness of 1.524 mm. The circuit material is laminated with 0.035-mm-thick copper foils on both sides of the dielectric material. This miniature quad-frequency resonator is representative of how this transmission-line technology can be applied to allow for multiple frequency bands while also miniaturizing the circuit size.



3. Here's a photo of the fabricated quad-band resonator constructed with a CRLH cell coupled with a D-CRLH cell.

Figure 4 shows the S-parameters of the proposed design, revealing four resonant frequencies: 3.9, 4.6, 6.2, and 7.1 GHz.

The return loss at these frequencies is equal to 18, 11, 12, and 11 dB, respectively. The respective insertion loss at the four frequencies is 2, 0.57, 0.32, and 4 dB.

Figure 5 compares the quad-frequency resonator's measured and simulated performance. The 3-dB bandwidth of the first band is 36.5 MHz; the 3-dB bandwidth of the second band is 84.5 MHz. For the third and fourth bands, the 3-dB bandwidths are 250 and 320 MHz, respectively. Hence, the quality factors (Qs) for the four respective bands are calculated as 106.84, 54.43, 24.8, and 22.187.

CONCLUSION

In this article, we introduced a new form of compact quad-band bandpass filters based on hybrid techniques. The resonant frequency of this type of filter can be easily tuned. In addition, the Qs are very high with sharp responses. As stated earlier, this miniature quad-frequency resonator represents how this transmission-line technology can be applied to allow for multiple frequency bands while also miniaturizing the circuitry.

The novel D-CRLH/CRLH structure used in the quad-frequency resonator is designed with two cells coupled together. The CRLH cell is responsible for generating the two lower-frequency bands, i.e., the first and second bands. Meanwhile, the D-CRLH cell generates higher-frequency resonance, which corresponds to the third and fourth bands. This work is significant in terms of research for multi-frequency bandpass filters. mw

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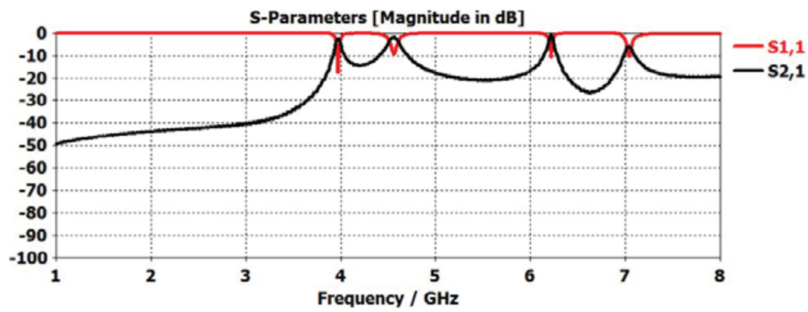
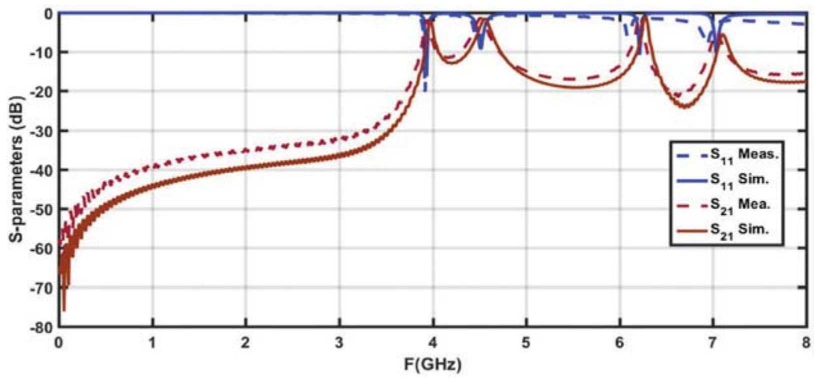


4. The plot reveals S_{21} and S_{11} simulation results of the proposed design.



5. The simulation results are in close agreement with the S_{21} and S_{11} measurements of the quad-frequency resonator.

FARRON DACUS | RF Design Consultant, Longwing Technology
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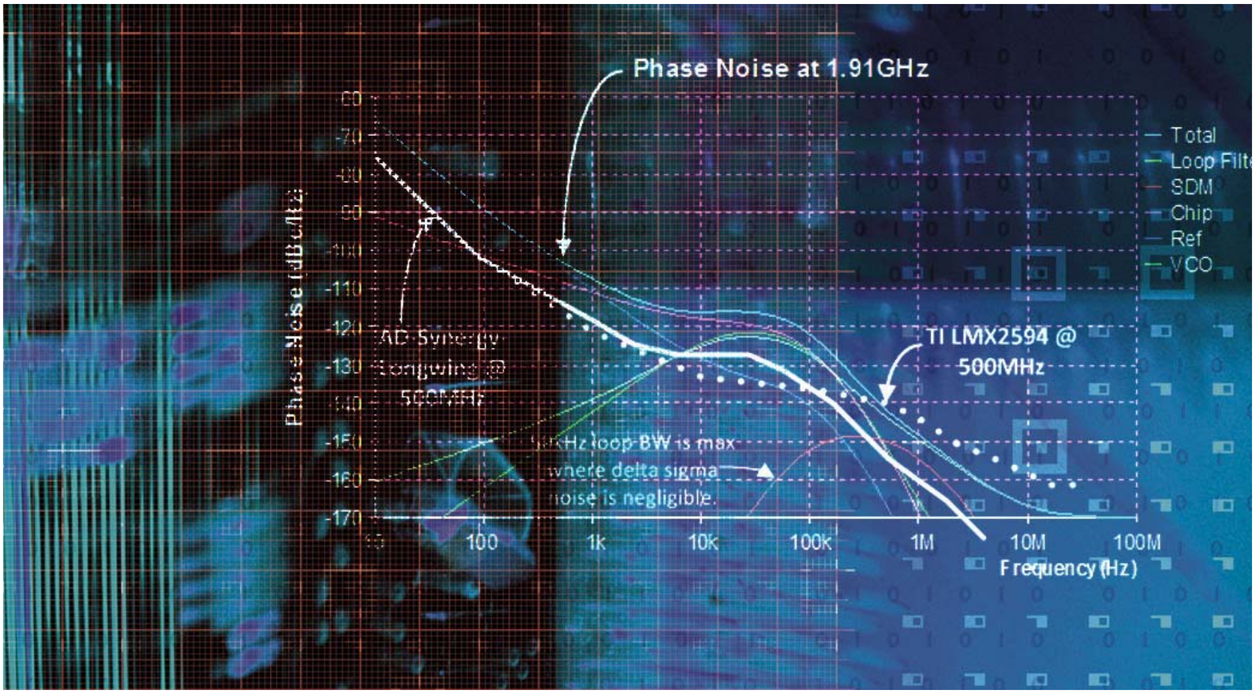


Low-Noise Synthesizer Design Examples

In the final chapter of this five-part series, we'll look at five different synthesizer designs, comparing fully integrated synthesizers to discrete implementations.

This article is the fifth and concluding installment in this series on ultra-low-noise synthesizers. Part 1 (Dec. 2018) introduced higher-order phase-locked-loop (PLL) design, while Part 2 (Feb. 2019) reviewed noise sources. Part 3 (Mar. 2019) analyzed noise shaping in the loop followed by Part 4 (Oct. 2019), which presented commercially available parts for the low-noise PLL designer.

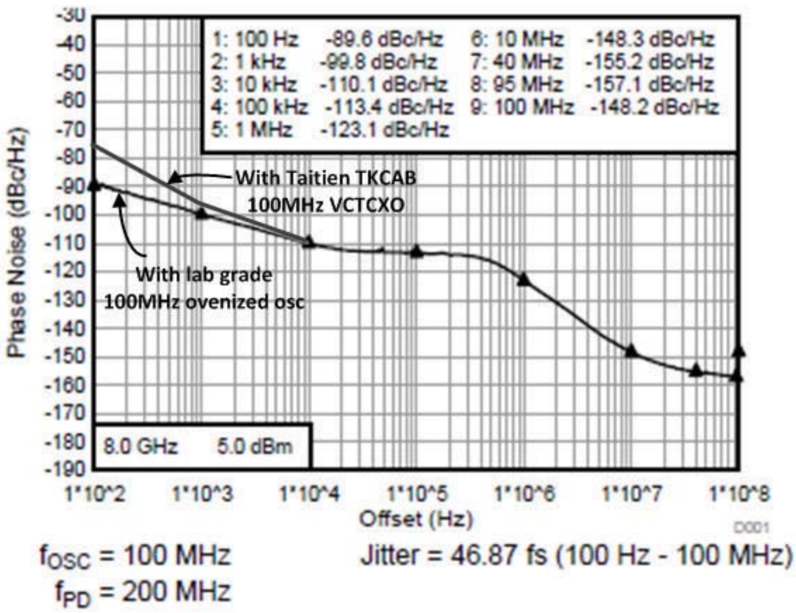
Longer and more detailed versions of these articles are available for download at *www.longwingtech.com*. This final article is intended to focus on the noise-performance results and tradeoffs in design examples using the low-noise techniques and parts presented earlier. Here, we compare the best performance available with fully integrated synthesizers to that which is possible with discrete voltage-controlled oscillators (VCOs) and external active filters.

EXAMPLE 1: FULLY INTEGRATED HIGH-PERFORMANCE SYNTHESIZER

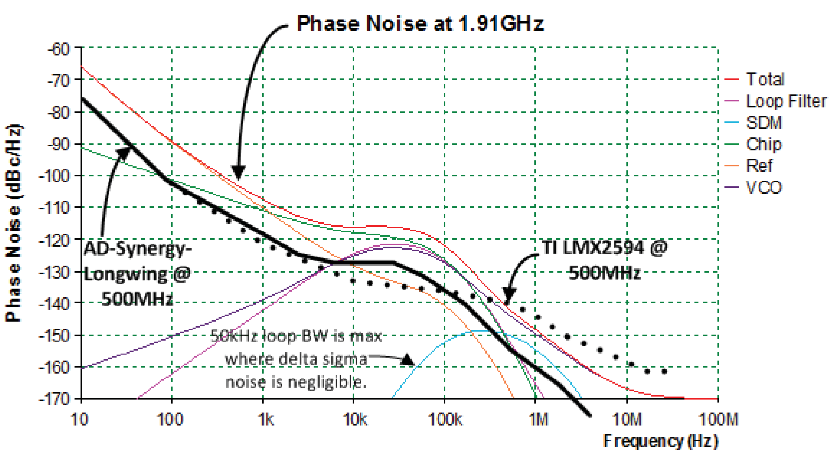
An outstanding example of a state-of-the-art device of this type is Texas Instruments' (TI) *(www.ti.com)* LMX2594/95 (LMX2595 is the higher-frequency version). Its performance will be shown both here and in the phase-noise graphs of several other solutions for comparison. The phase noise at an output frequency of 8 GHz is shown in *Figure 1* (taken from the datasheet). Design and phase-noise prediction may be quickly performed using the "PLLatinumSim" program found on TI's website. For more detailed control of the design than the assumptions in this program, the author recommends the methods developed earlier in this series using an analysis program such as Mathcad.

At 8 GHz, the LMX2594 on-die VCO has an open-loop phase noise of approximately –80 dBc/Hz at 10-kHz offset. This number represents a good but not great noise level. It's good enough to allow for effective suppression in the loop to approach the device's industry-leading Pn1Hz of –235 (fractional mode). However, it's not possible to achieve suppression all the way down to the limit implied by this floor. That's because the VCO noise and 1/f noise in the synthesizer are too high to allow that with the maximum loop bandwidth on the order of 300 kHz.

Despite this internal noise limit, the LMX2594 does deliver quite excellent performance, which is a challenge for discrete VCO synthesizers to beat. The integrated noise and adjacent-channel-rejection limits of the LMX2594 are shown in the long-form article.



1. Depicted is the phase noise of the LMX2594 at an output frequency of 8 GHz. The loop bandwidth is about 300 kHz.



2. A high-quality discrete land-mobile synthesizer with 50-kHz bandwidth is compared to TI's LMX2594 with 300-kHz bandwidth.

EXAMPLE 2: DISCRETE LAND MOBILE SYNTHESIZER

Land-mobile radio is an application that requires low phase noise due to its closely spaced 12.5-kHz channels (see long form of Part 3). Let's now compare the LMX2594 with the more classic low-noise discrete VCO approach.

VCO: For this relatively narrowband application, we select the Synergy Microwave *(www.synergymwave.com)* DCRO178205-10 VCO that covers 1,785 to 2,060 MHz.

Synthesizer: Analog Devices *(www.analog.com)* ADF41513, Pn1Hz = –231 in fractional mode. Using this synthesizer, we will perform basic analysis and simulation with the convenient Analog Devices "SimPLL" program.

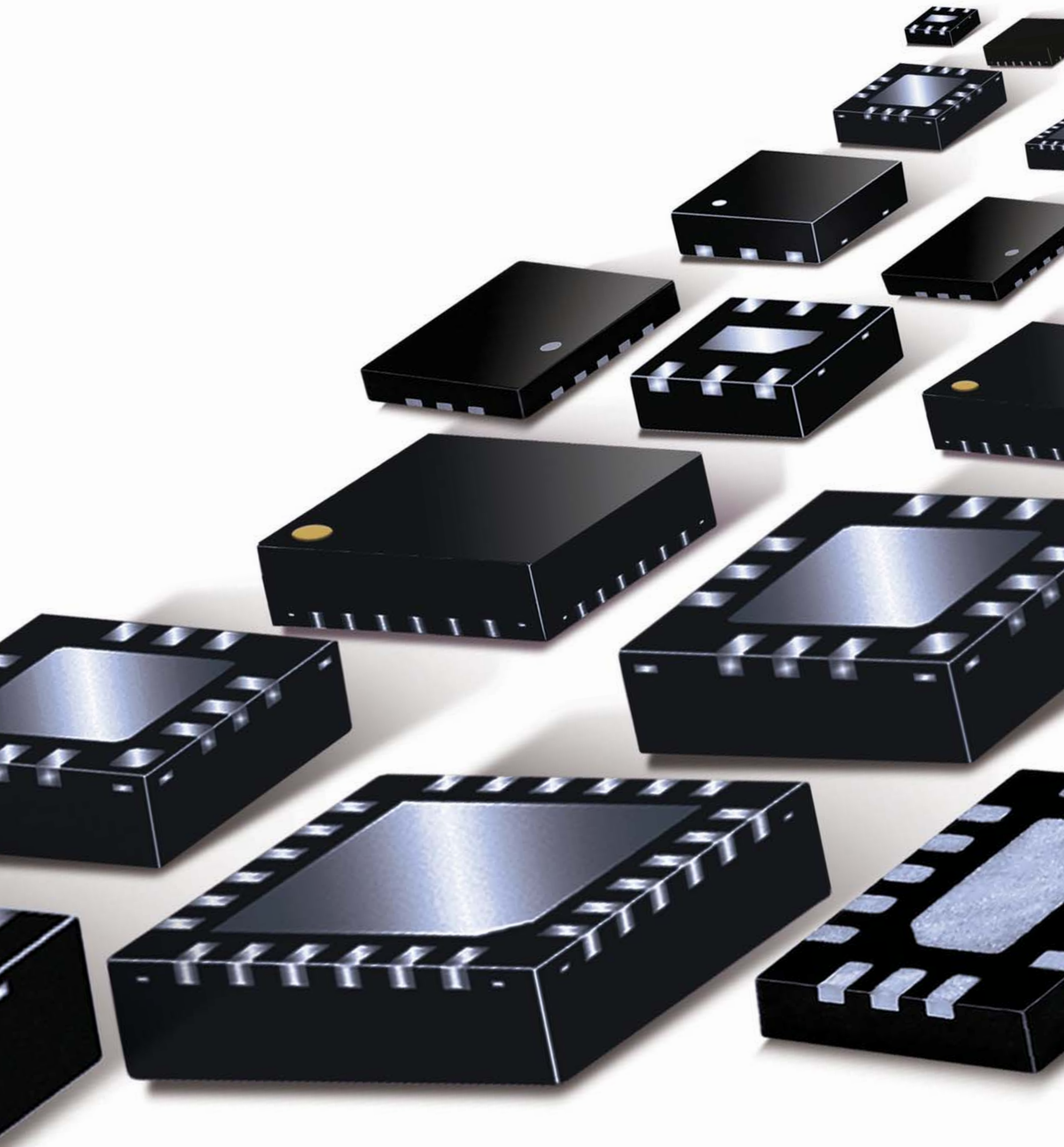
Crystal reference: Taitien *(www.taitien.com)* TKCAB 100-MHz voltage-controlled temperature-compensated crystal oscillator (VCTCXO).

Loop filter: Custom Longwing active implementation that provides 0 to 12 V.

Loop: Bandwidth of 50 kHz and phase margin of 60 degrees.

We see in *Figure 2* that the Synergy-Analog solution is similar to the LMX2594 up to about 3 kHz, but it's inferior from 3 to 100 kHz by as much as 8 dB. This solution then achieves superior performance above 100 kHz. The superiority of the Synergy-Analog solution with a custom Longwing active filter at 200 kHz is about 6 dB before increasing to about 16 dB at 1 MHz.

From *Figure 2*, this discrete synthesizer divided down to about 500 MHz would achieve an LdB(flat) of about –129dBc/Hz. It meets the 12.5-kHz adjacent-channel-noise requirement derived in Part 3 with a margin of 4 dB on top of the 10 dB that's built into that requirement. However, while this approach satisfies noise requirements, it's less flexible and moderately more expensive than a fully integrated synthesizer solution such as the LMX2594. Thus, this approach is really only jus-



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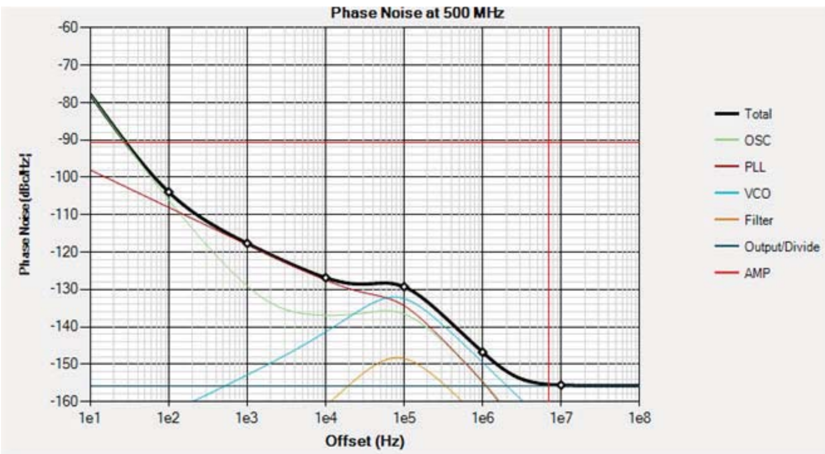
tified if moderately lower power consumption and better far out noise are required.

EXAMPLE 3: HANDHELD LAND MOBILE SYNTHESIZERS WITH INTEGRATED VCOs (LMX2572 AND LMX2571)

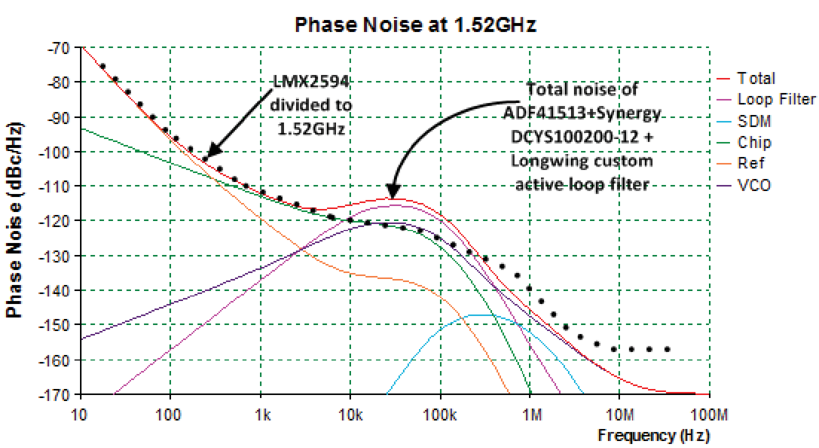
The land-mobile examples discussed above are suitable for vehicle or base-station radios. However, the higher current of the integrated VCO LMX2594 (approximately 340 mA) and higher tune voltage of the DCRO178205-10 VCO (12 V) make them less suitable for handheld transceivers.

A possible fully integrated solution with generous safety margin on noise performance is TI's LMX2572. This part, intended for battery-powered applications, has a supply requirement of 3.3 V at 75 to 86 mA. The phase noise shown in *Figure 3* corresponds to a 6-GHz VCO that's divided by 12 to 500 MHz for land-mobile use.

This device meets the land-mobile requirement of average LdB of –125dBc/Hz from 6.25 to 18.75 kHz with about 3 dB of margin. As the requirement has a safety margin of 10 to 12 dB built in, the safety margin here likely approaches 15 dB over statutory requirements.



3. Shown is the LMX2572 phase noise at 500-MHz output with Taitien's TKCAB 100-MHz reference. The loop bandwidth is 150 kHz.



4. This is the 1.15- to 2-GHz noise using the Synergy DCYS100200-12 VCO, Analog Devices' ADF41513 synthesizer chip, Taitien's TKCAB 100-MHz VCTCXO, and the Longwing active loop filter.

The LMX2571 is an even lower power TI delta-sigma synthesizer designed for battery-powered applications. This synthesizer has integrated VCOs, but it can also accept external VCOs. In external VCO mode, its power requirements can extend down to 9 mA. It can come within about 5 dB of the adjacent-channel-noise performance of the LMX2572, which is generally sufficient for portable radios.

EXAMPLE 4: DISCRETE BROADBAND SYNTHESIZER FROM 1 TO 2 GHZ (CELLULAR BASE STATION)

The cellular-base-station application is one that may need superior far out noise compared to what's provided by an integrated VCO. Here, we can afford the moderately higher price of the necessary low-noise active loop filter and low-noise higher-voltage power supplies.

VCO: For this wider-band application we select the Synergy DCYS100200-12 VCO, which covers a frequency range of 1 to 2 GHz. This part is among Synergy's lowest normalized-noise performing octave-range VCOs. It does require 12 V for power and 28 V for tuning. *Figure 4* show noise for a range of 1.15 to 2 GHz, as 1.15 GHz is the lowest frequency that allows an Fpd (phase detector frequency) of 50 MHz.

Synthesizer: Analog Devices ADF41513, Pn1Hz = –231 in fractional mode.

Crystal reference: Taitien TKCAB 100-MHz VCTCXO.

Loop filter: Custom Longwing active implementation that provides 0 to 28 V.

Loop: Bandwidth of 55 kHz and phase margin of 60 degrees.

Here, we note that this discrete solution is nearly identical to the integrated LMX2594 solution at close-in frequencies—it's inferior from 50 to 200 kHz and then superior beyond about 200 kHz. The superior far-out performance would be the main reason to select this design over the moderately more cost-effective fully integrated solution. The

adjacent-channel implications are given in the long form.

EXAMPLE 5: DISCRETE VCO SYNTHESIZER (RFID) FROM 902 TO 928 MHZ

Radio-frequency identification (RFID) is an application that calls for outstanding phase noise in the reader. Superb VCOs are available for this application.

VCO: Z-Comm's *(www.zcomm.com)* ZRO0915 is the lowest normalized-noise VCO on the market with significant tune range. Only very narrow SAW-based oscillators have lower noise than this device.

Synthesizer: Analog Devices ADF41513, Pn1Hz = –231 in fractional mode.

Crystal reference: Taitien 6800 ovenized part.

Loop filter: Custom Longwing active implementation that provides 0 to 12 V.

Loop: Bandwidth of 12 kHz and phase margin of 55 degrees.

Despite the very low noise of the ZRO0915, the limit of 25 MHz for Fpd when using a 100-MHz reference oscillator makes the noise performance around the loop bandwidth inferior to the LMX2594 solution *(Fig. 5)*. Beyond the loop bandwidth, the performance is significantly superior.

FINAL SUMMARY

This five-part series has centered on creating a detailed understanding of noise sources, shaping, and performance in modern synthesizer design. A key issue was if and when synthesizers designed with the classic method of packaged VCOs could outperform the latest fully integrated synthesizers with on-die VCOs. The answer is that, for most applications, the integrated noise VCO performance is perfectly fine, though for some portable applications the power consumption may not be acceptable.

This five-part series has centered on creating a detailed understanding of noise sources, shaping, and performance in modern synthesizer design.

However, beyond the loop bandwidth that's generally in the range of 40 to 400 kHz, the discrete VCO approach is still superior by amounts that can exceed 20 dB. This is important in

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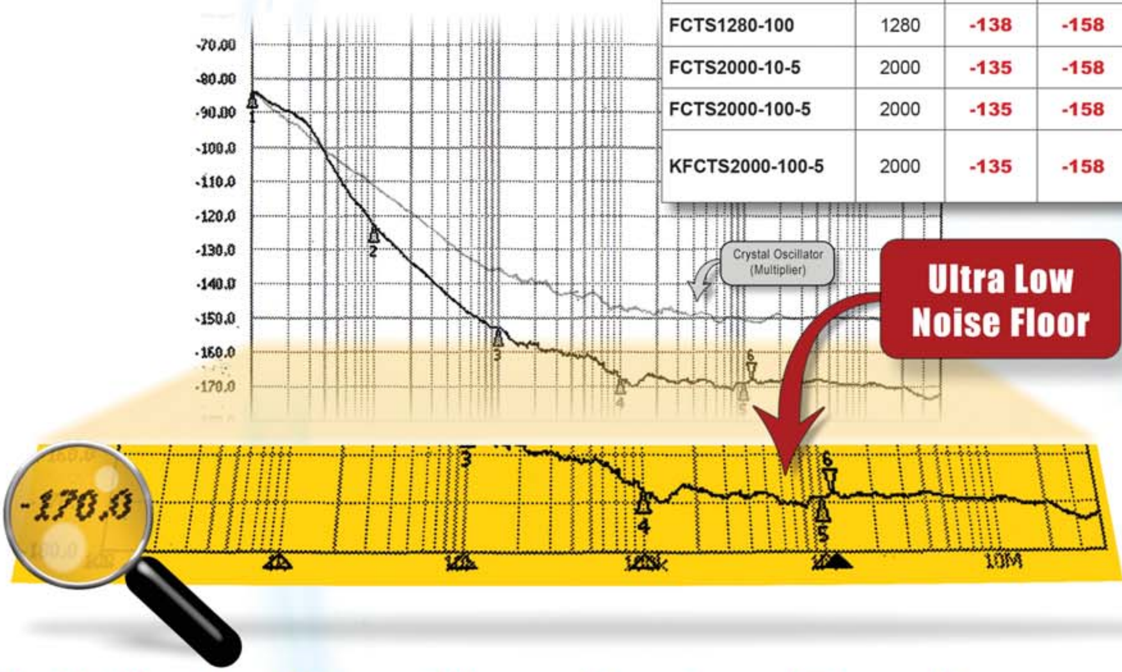
Model	Frequency (MHz)	Phase Noise (dBc/Hz) [Typ.]		Package
		@10 kHz	@100 kHz	
VFCTS128-10	128	-155	-160	
FCTS800-10-5	800	-144	-158	
KFCTS800-10-5	800	-144	-158	
FSA1000-100	1000	-145	-160	
KFSA1000-100	1000	-145	-160	
FXLNS-1000	1000	-149	-154	
KFXLNS-1000	1000	-149	-154	
FCTS1000-10-5	1000	-141	-158	
KFCTS1000-10-5	1000	-141	-158	
FCTS1000-100-5	1000	-141	-158	
FCTS1000-100-5H	1000	-144	-160	
FCTS1040-10-5	1040	-140	-158	
FCTS1280-100	1280	-138	-158	
FCTS2000-10-5	2000	-135	-158	
FCTS2000-100-5	2000	-135	-158	
KFCTS2000-100-5	2000	-135	-158	



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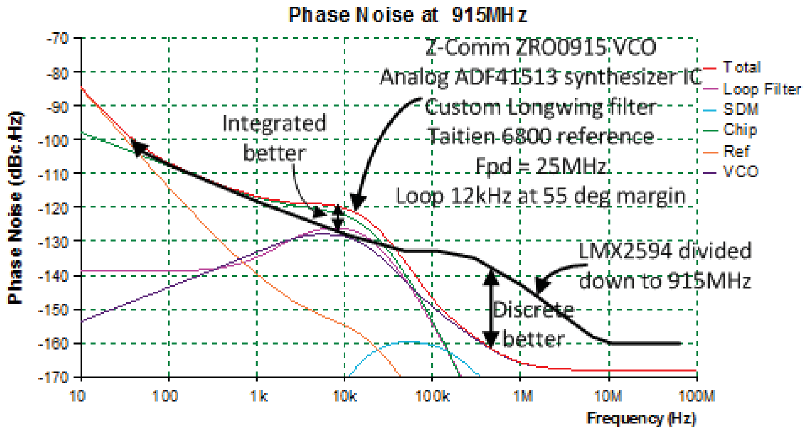
some applications. However, few VCOs have that large of a performance advantage over integrated VCOs. And to the author's knowledge, there are currently no VCOs above 4 GHz for which the full advantages of the high-bandwidth delta-sigma synthesizer can be applied. These architectural advantages and how they are best applied are discussed in detail in the earlier parts of this series.

For the discrete VCO approach to regain its previous market dominance in low-noise applications, VCOs must achieve low normalized phase noise at frequencies above 4 GHz that's comparable to the performance of the best lower-frequency VCOs. This possibility is explored in the long form of this article. mw

LONG FORMS OF THESE ARTICLES that contain more detail are posted at www.longwingtech.com.



5. The Z-Comm ZRO0915 ultra-low-noise VCO locked up by the ADF41513 synthesizer with Taitien's 6800 100-MHz reference. The 12-kHz loop bandwidth employed here is the maximum that can be used while keeping the delta-sigma noise invisible. The Longwing ultra-low-noise active filter used here improves noise performance around the loop bandwidth by about 2 dB over a standard low-noise active filter.

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Design Feature

FAYCAL AMRANI | Laboratory of instrumentation (LINS), electronic and computer science faculty, University of Sciences and Technologies Houari Boumedien (USTHB), Bab Ezzouar, Algiers, Algeria

M. TRABELSI | Department of Electrical and Electronic Engineering, Telecommunication Laboratory of ENP, Algiers, Algeria

Apply a New Approach to Dual-Fed Distributed Amplifier Design

This novel design method helps improve gain for the dual-fed DA by approximating gain using the Chebyshev polynomial.

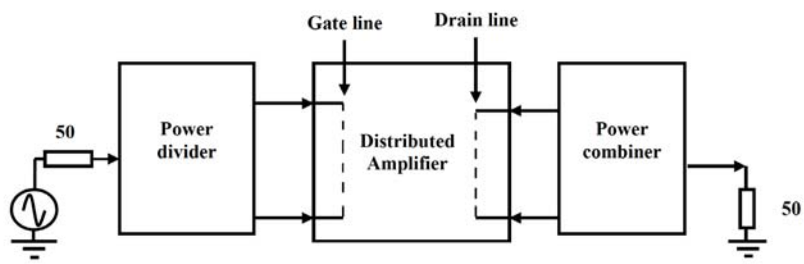
The topology of the balanced amplifier[1] allows for power to be added at the output. It's composed of two amplifiers, which may be multistage implementations, placed between the input power divider and the output power combiner *(Fig. 1)*. To enhance the design, a device known as the "Dual-Fed Distributed Amplifier" (DFDA), has been introduced.[2]

The operating principle of the DFDA involves injecting the signal to be amplified into both ends of the gate line. The output signal is recovered at the two ports of the drain line.

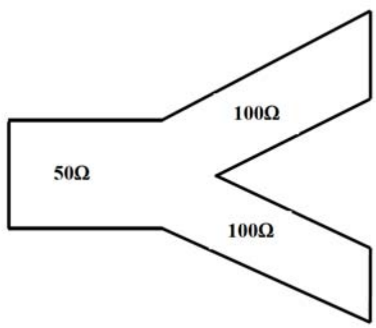
The DFDA is characterized by:[2]

- A 6-dB increase in gain compared to the conventional distributed amplifier (CDA)[3] due to the direct and indirect gains being added. This is not the case with a CDA, in which only the direct gain is taken into account.
- A lower noise factor than that of the CDA due to the absence of the 50-Ω impedance at the ends of the gate and drain lines.

Using two transistors, it's possible to obtain an open-circuit line at the ends of the gate and drain lines.[4] While the gain improves, the bandwidth remains less than that of the CDA.



1. The DFDA amplifier configuration includes an input power divider and an output power combiner.



2. The T-piece contains two 100-Ω transmission lines.

This article presents a new DFDA design technique that allows for a stable gain over the entire bandwidth. The new amplifier is called a mismatched DFDA (MDFDA). The technique is based on the approximation of the amplifier transducer gain by the Chebyshev polynomial.

AMPLIFIER DESIGN

For this amplifier, the input and output power dividers are replaced by a simple T-piece composed of two 100-Ω transmission lines of unspecified length *(Fig. 2)*. The value of 100 Ω was chosen to match the input with the amplifier's gate line, as well as the output with the amplifier's drain line. The values of the components of the gate and the drain line are obtained by approximating the amplifier gain with the Chebyshev polynomial.

The amplifier diagram of *Figure 3* reveals a symmetric plane, meaning that such amplifiers are a product of the association of two identical half-circuits. Thus, the analysis of this type of amplifier will be based on that of a half-circuit.

The symmetric plane corresponds to an open circuit. Inductances are elements with constants localized; the equivalent diagram of the half-circuit is shown in *Figure 4*. This diagram is equivalent to that of the single-stage distributed amplifier (SSDA)[5] except that the source and load impedance values are doubled ($2Z_O = 100\ \Omega$).

To express the amplifier's transducer gain, we use the simple unilateral model of the MESFET transistor, shown inside the dashed line in *Figure 4*. Here, C_g and C_d are the gate and drain capacitances, respectively, of the field-effect transistor (FET) in common-source mode, while g_m is the transconductance. For this structure, the transducer gain, G_T, is:

$$G_T = \frac{-\frac{1}{2}R_e(V_2 i_2^*)}{|E_g|^2/16Z_0} \quad (1)$$

where V_2 and i_2 are the output voltage and current, respectively.

The transducer gain then becomes:

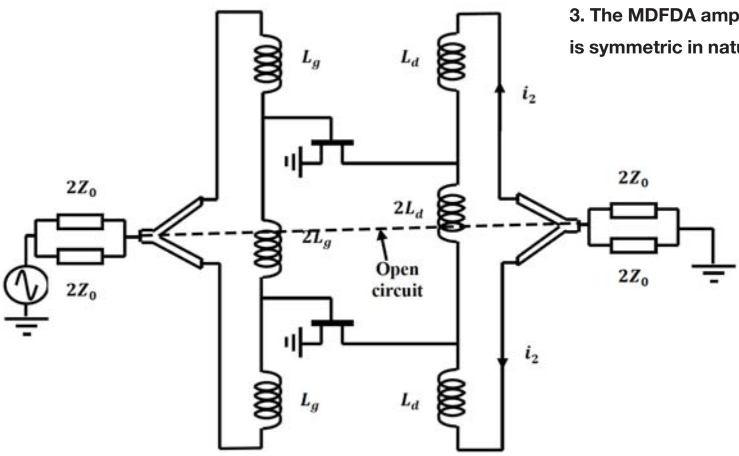
$$G_T = \frac{16Z_0^2 g_m^2}{[(1-4x^2)^2 + \alpha_1^2 x^2][(1-4a^2x^2)^2 + \alpha_2^2 a^2 x^2]} \quad (2)$$

where $x = \omega/\omega_{c1}$ is the normalized frequency with respect to the cutoff frequency of the gate line. The other variables are defined as:

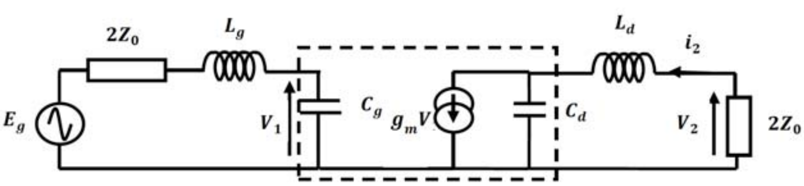
$$\omega_{c1} = 2/\sqrt{L_g C_g},\ \alpha_1 = 4Z_0/Z_{c1},\ \alpha_2 = 4Z_0/Z_{c2},$$

and

$$a = \omega_{c1}/\omega_{c2}$$



3. The MDFDA amplifier is symmetric in nature.



4. Shown is the equivalent MDFDA half-circuit.

Z_{c1} and Z_{c2} are the characteristic impedances at relatively low frequencies of the K-constant circuits constituting the gate and drain lines, respectively. They are defined as:

$$Z_{c1} = \sqrt{L_g/C_g}$$

$$Z_{c2} = \sqrt{L_d/C_d}$$

The cutoff pulsation of the drain line is:

$$\omega_{c2} = 2/\sqrt{L_d C_d}$$

We can then get the following results:

$$g_T = G_T/16Z_0^2 g_m^2 \quad (3.1)$$

$$g_T = 1/(1 + A_2x^2 + A_4x^4 + A_6x^6 + A_8x^8) \quad (3.2)$$

where:

$$\begin{cases} A_2 = a^2(\alpha_2^2 - 8) + (\alpha_1^2 - 8) \\ A_4 = 16a^4 + a^2(\alpha_1^2 - 8)(\alpha_2^2 - 8) + 16 \\ A_6 = 16a^4(\alpha_1^2 - 8) + 16a^2(\alpha_2^2 - 8) \\ A_8 = (16)^2 a^4 \end{cases} \quad (3.3)$$

The approximation by the Chebyshev polynomial will be applied to the denominator of Equation 3.2. This approximation consists of writing the denominator of g_T in the $D = 1 + Q_n(x)$ form, or:

$$D = (1-\varepsilon'^2)\left[1 + \varepsilon^2\left(1 + (Q_n(x)/\varepsilon'^2)\right)\right] \quad (4)$$

Here, $\varepsilon^2 = \varepsilon'^2 / 1 - \varepsilon'^2$ represents the ripple ratio. We then carry out the approximation by using the Chebyshev polynomial of $T_n^2(x)$ of one part of the denominator as follows:

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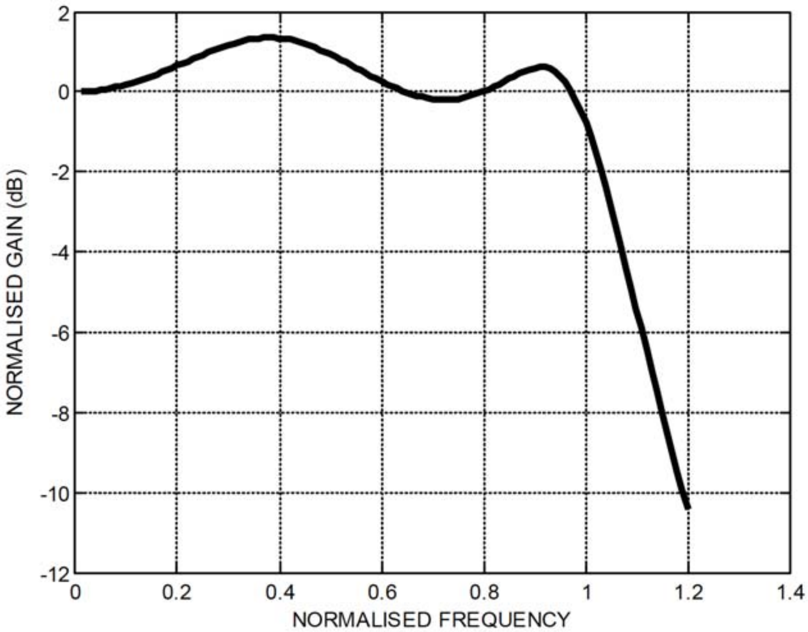

5. Shown is the MDFDA's normalized power gain as a function of the normalized frequency.

$$1+\varepsilon^2\left(1+(Q_n(x)/\varepsilon'^2)\right)=1+\varepsilon^2T_n^2(x) \quad (5)$$

Therefore:

$$T_n^2(x)=1+(Q_n(x)/\varepsilon'^2) \quad (6)$$

As $Q_n(x)$ is of the eighth degree, $T_n^2(x)$ must also be:[6]

$$T_n^2(x)=64x^8-128x^6+80x^4-16x^2+1 \quad (7)$$

After identification, Equations 3 and 7 imply the following set of equations:

$$\begin{aligned}A_8&=64\varepsilon'^2\\A_6&=-128\varepsilon'^2\\A_4&=80\varepsilon'^2\\A_2&=-16\varepsilon'^2\end{aligned} \quad (8)$$

where A_i $(i = 2, 4, 6, 8)$ are the coefficients given by Equation 3.3.

Therefore, to design the MDFDA implementation, we must initially solve for the equations shown in the Equation 8 set, in which the roots are α_1, α_2, α, and ε'. The values taken by these roots are the same regardless of the characteristics of the FET used.

The resolution of equations in the Equation 8 set leads to the following result:

$$\alpha_1=2.38;\alpha_2=0.556;a=0.511\ and\ \varepsilon^2=0.37 \quad (9)$$

With the values of Equation 9 and by taking $Z_O = 50\ \Omega$, the design parameters as a function of the gate capacitance, C_g, can be derived as:

$$C_d=0.13C_g;\ L_g=7120C_g\ and\ L_d=15448C_g \quad (10)$$

We then just need to know the value of C_g to proceed to the design of the amplifier.

The results given by Equations 9 and 10 are general and can thus be applied to any FET. Therefore, it's sufficient to only know the value of C_{gs} to proceed to the amplifier design.

Several points can be noted from the obtained results. The FETs with a value of C_d/C_g of less than 0.13 require a shunt capacitor to be added to the drain. The added capacitors combine with C_d to form a new capacitor, C_d', such that $C_d'/C_g = 0.13$. The shunt capacitor at the gate should be avoided, since it leads to a reduction of the bandwidth.

We can update the Equation 3.3 set and then Equation 3.2 with the values given in Equation 9 to calculate the normalized power gain as a function of the normalized frequency for the MDFDA amplifier. *Figure 5* reveals the calculated gain. The main characteristic is that this curve is universal. It should be noted that the MDFDA amplifier with a gain that's approximated by the Chebyshev polynomial achieves a stable gain over a large bandwidth. Here, the bandwidth is defined as a band of frequencies in which the gain is constant or has small variations.

DESIGN AND SIMULATION

We now will carry out the design and simulation of the amplifier studied previously. The internal parameters of the selected transistor are $C_{gs} = 0.17$ pF, $C_{ds} = 0.006$ pF, and $g_m = 32$ mS. The substrate chosen for the microstrip lines is characterized by its relative permittivity, ε_r, of 10.2. The height of the dielectric and the conductor thickness are 0.25 mm and 17 µm, respectively.

The TXLINE program within the Microwave Office design software was used to calculate the dimensions of the 100-Ω lines of the T-piece. Microwave Office software was used to perform all simulations.

The calculation of the widths (W) of the 100-Ω lines of the T-piece produced a value of 20.129 µm.

Using the equations shown in the Equation 10 set, we determine that $L_g = 1210.4$ pH, $L_d = 2626.16$ pH, and $C_d = 0.0224$ pF. The shunt capacitor with the addition of C_{ds} is:

$$C=C_d-C_{ds}=0.022-0.006=0.016pF$$

The transducer gains of the MDFDA were simulated with Microwave Office. The results are provided later in the article.


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USING THE REAL TRANSISTOR EQUIVALENT CIRCUIT

The study here assumed a unilateral transistor with an almost infinite capacitive output impedance value over the bandwidth considered. However, a real transistor does not achieve such characteristics. *Figure 6* shows an equivalent circuit of a real transistor. Here, C_{gd} = 0.016 pF, R_{ds} = 560 Ω, and R_{gs} = 0.53 Ω.

The circuit that's best suited for this study is the cascode circuit, in which an inductance is added between two transistors to reduce the effects of the input and output capacitances of the first and the second transistors, respectively, at high frequencies *(Fig. 7)*. *Figure 8* shows the equivalent circuit of the cascode circuit.

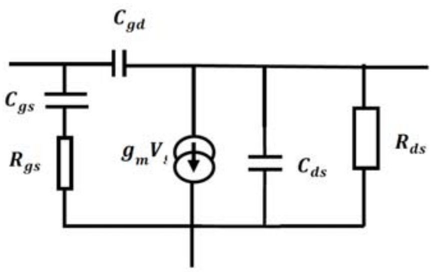
Ref. 5 reveals that, unlike a single-transistor circuit, the cascode implementation is a practically unilateral circuit that achieves an almost infinite output impedance. Thus, to design the MDFDA, we just need to replace the transistors in *Figure 3* with cascode circuits.

The shunt capacitor added at the output of the cascode circuit is equal to 0.006 pF. This is because we have the capacitor C_{gd} of the second transistor at the output of the cascode circuit. The value of the shunt capacitor is then calculated as:

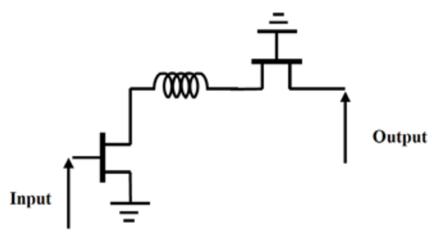
$$C = C_d - C_{gd} = 0.022 - 0.016 = 0.006pF$$

The value of the inductance (400 pH) between the two transistors of the cascode is obtained via optimization.

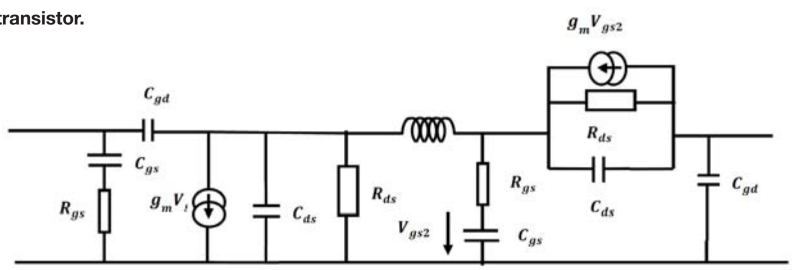
Figure 9 shows the simulated gains of the MDFDA using a unilateral transistor, a real transistor, and the cascode circuit. With a unilateral transistor, we can see that the gain is stable over the entire bandwidth. However, in reality, transistors are not unilateral, causing the gain and the bandwidth to decrease when using a real transistor versus a unilateral one. With the cascode circuit, we obtain good results—the gain of the amplifier is almost the same as the amplifier that employs a unilateral transistor.



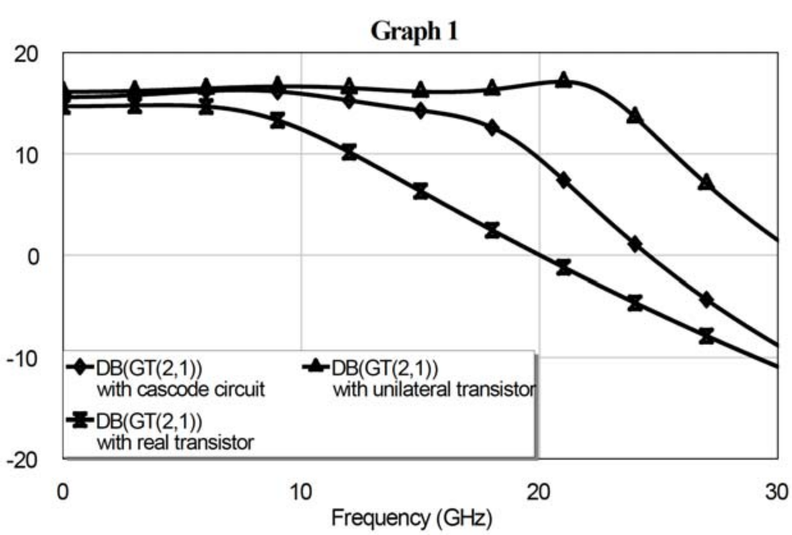
6. This is the equivalent circuit of a real transistor.



7. The cascode circuit contains an inductance between the transistors.



8. This circuit represents the equivalent of the cascode circuit.



9. Shown are the simulated gains of the MDFDA using a unilateral transistor, a real transistor, and the cascode circuit.

CONCLUSION

This new design approach for the DFDA can apply to any MESFET transistor. The technique makes it possible to maintain a stable gain over a large frequency range due to the approximation of the amplifier gain by the Chebyshev polynomial. The design parameters can be determined in a very simple manner—one only needs to know the gate capacitance of the transistor. This approach allows for a distributed amplifier with substantial gain over a broad bandwidth. mw

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defense electronics

A Special Section to INFORMA'S DESIGN ENGINEERING & SOURCING GROUP DECEMBER 2019

Mobile Encryptor Earns NSA's TS/SCI Certification

JACK BROWNE | Technical Contributor

THE NATIONAL SECURITY AGENCY (NSA) has certified the TACLANE-Nano (KG-175N) network encryptor developed by General Dynamics Mission Systems *(www.gd.com)* for communications security levels as high as top secret/sensitive compartmented information (TS/SCI). The encryptor can protect the most critical data communications through government networks and national security systems worldwide at any time.

The TACLANE-Nano (KG-175N) network encryptor *(see figure)* was developed according to military reduced size, weight, power, and cost (SWaP+C) initiatives and can operate at aggregate speeds exceeding 100 Mb/s. Despite the small size, it can handle the demands of a mobile communications environment. It's flexible and portable enough for rapid tactical forward deployment for manned and unmanned intelligence, surveillance, and reconnaissance (ISR) missions, as well as covert and special operations.

The compact TACLANE-Nano (KG-175N) network encryptor carries the NSA's TS/SCI certification for the most sensitive missions. *(Courtesy of General Dynamics Mission Systems)*

"General Dynamics is committed to advancing our TACLANE portfolio to address our customers' unique mission needs from enterprise to edge," said Brian Morrison, vice president and manager of the Cyber Systems line of business for General Dynamics Mission Systems. "This certification makes TACLANE Type 1 encryption available in a ruggedized low SWaP form factor to bring our proven data security to the tactical edge of the battlefield." de

Air Force Develops Turbine Totally In-House

SPEED IS OFTEN a must-have in the development of new technologies for the armed forces. As part of accelerated efforts to design and build a new type of turbine engine, the Responsive Open Source Engine (ROSE) was designed, built, and tested by the U.S. Air Force Research Laboratory (AFRL) at Wright-Patterson Air Force Base (Ohio) in just 13 months—the first turbine engine designed, assembled, and tested exclusively in-house. This project by the Aerospace Systems Directorate is evidence of the Air Force's desire to develop new technologies and prototypes in less time and with less cost.

"We decided the best way to make a low-cost, expendable engine was to separate the development costs from procurement

(Continued on page 46)

Bacteria May Help Detect Buried Explosives

BACTERIA ARE TYPICALLY thought of as health threats, but they may soon become battlefield allies. Raytheon is exploring the use of synthetic biological science to create a new method for detecting buried explosives. Working with partner Worcester Polytechnic Institute under a contract from the U.S. Defense Advanced Research Projects Agency (DARPA), the research involves programming two strains of bacteria to monitor ground surfaces for explosive materials.

One strain of bacteria will be programmed to search for buried explosives. If it detects explosives under the ground surface, the second strain of bacteria will produce a glowing light on the surface of the ground in the area of detection. That, in turn, will signal remote cameras or robotic systems such as unmanned aerial vehicles (UAVs) or unmanned ground vehicles (UGVs) with electro-optical (EO) or infrared (IR) cameras/sensors to communicate information about the location of the explosives underground. de

Even the Military is Making Plans for 5G

JACK BROWNE | Technical Contributor

COMMUNICATIONS IS A CRITICAL PART of any military efforts and links must be reliable, secure, and without delays. Defense/aerospace designers have typically led the way with technologies for advanced communications systems, such as active antenna arrays and software-defined radios (SDRs). With 5G cellular wireless networks, they are about to see some of those technologies come back in commercial form, in support of systems that will wirelessly connect billions if not trillions of people and things to the internet and each other.

Of course, it was DARPA that developed the internet, initially for military use, and it's the U.S. Department of Defense (DoD) that announced interest in integrating 5G technology and systems into their own future communications strategies, namely their Defense Next Generation Information Communications Technology planning. Industry partners well-versed in 5G technology are expected to be busy when the DoD's requests for proposals (RFPs) are made public.

The DoD is working closely with the Federal Communications Commission (FCC) and other government organizations on how to make use of the many advanced technologies and wide chunks of frequency spectrum enabling 5G wireless systems. By working with the DoD-sponsored National Spectrum Consortium, for example, the DoD has received design inputs from a wide range of 5G equipment suppliers as starting points for military systems employing 5G technology.

The same applications that are attractive for commercial and industrial 5G applications, such as Internet of Things (IoT) sensors for smart homes and smart cities, may provide smart warehouses or even smart training grounds for military troops. The instant internet access via high-speed data links at mmWave frequencies supports fast data transfers, for example, between surveillance UAVs *(see p. 48)* and their controllers. Military specifiers will also benefit from the commercial-off-the-shelf (COTS) availability and pricing that 5G will bring to mmWave components, as new frequencies and spectrum open new vistas for military system designers. de

Air Force Turbine

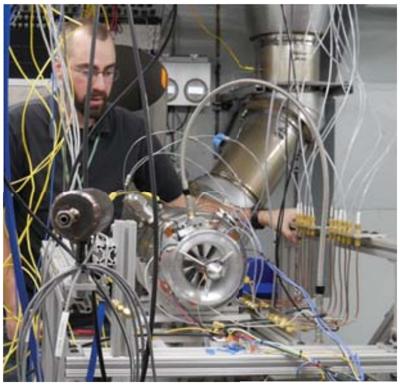
(Continued from page 43)

costs," said Frank Lieghley, Aerospace Systems Directorate Turbine Engine Division senior aerospace engineer and project manager. Since the design and development of the turbo engine were performed in-house, the Air Force owns the intellectual property (IP) behind the engine. With command of the IP, once the engine design is tested and qualified, there's flexibility in the choice of manufacturers to produce the engine. That means small production runs are possible, rather than being held to larger production runs from large prime contractors simply to minimize costs.

By developing the engine in-house, costs have been reduced dramatically over competitive alternative engines. The lower cost of the small engine creates opportunities to develop a new class of air vehicles. "There's no end to what might be done, but it's all enabled by inexpensive production," said Dr. Greg Bloch, Aerospace Systems Directorate Turbine Engine Division chief engineer. "It's the ability to turn the economics of warfare around."

The ROSE project is not meant as a strategy to replace prime contractors, but as an optional design and development path when needed. As explained by Lt. Col. Ionio Andrus, the Aerospace Systems Directorate Turbine Engine Division deputy division chief, "We're not trying to compete with our commercial partners; we are leveraging an underutilized sector to meet Air Force needs."

By working with other AFRL organizations, including the Materials and Manufacturing Directorate and the Air Force Institute of Technology, the engine design team leveraged enormous available internal expertise in different areas to help speed the project. It's the first example of what may be possible for many lower-cost, technological advances in the future.



A new turbine engine for smaller platforms was designed, built, and tested in-house by the U.S Air Force Research Laboratory at Wright-Patterson AFB. *(Courtesy of AFRL)*

DARPA Goes Fishing with Angler Program

IN PURSUIT of advanced underwater robotic systems, DARPA awarded six contracts for its Angler program for the development of deep-sea autonomous underwater vehicles (AUVs). The program seeks to leverage technology improvements in unmanned area vehicles (UAVs) and unmanned ground vehicles (UGVs) in undersea vehicles capable of operating without human control and without GPS guidance available to UAVs and UGVs *(see p. 48)*. The program is part of a global trend to increase the use of robotic systems in military activities, eventually achieving autonomous operation with the aid of artificial intelligence (AI).

The Angler program is divided into two tracks—A and B. Three companies were awarded contracts for Track A, which is focused on developing an integrated solution for all operating areas of the program: Leidos, Northrop Grumman, and L3-Harris. Contracts for Track B, aimed at developing solutions for the fields of navigation, autonomy, and perception, were awarded to SoarTech, EdgeTech, and Kitware.

Along with complementing existing robotic capabilities of UAVs in the air and UGVs on the ground, DARPA expects many benefits from the program, including the capability to achieve long-duration navigation and autonomy without GPS or surface-based communications links. DARPA also hopes the program will provide an autonomous undersea robotic system capable of deep-sea manipulation of objects and perception systems, aiding in the ability to "see" and grasp deep-sea objects even in degraded undersea environments.

This artist's conception shows a possible result of DARPA's Angler program for the development of autonomous undersea vehicles that can navigate without GPS guidance. *(Courtesy of DARPA)*

Major Investments Expected in Military Cybersecurity Market

CYBERSECURITY CAN BE a problem for anyone making purchases over the internet, but it is also an area of concern for military computer and communications equipment users. Market forecaster Frost & Sullivan, in their recent analysis "Global Military Cybersecurity Market, Forecast to 2023," expects the global military cybersecurity market to grow to more than $16 billion by 2023. The forecast predicts a compound annual growth rate (CAGR) of 3.6% from 2018 to 2023.

"Militaries across the globe are budgeting for and pursuing the development of new enabling, next-generation technologies for cybersecurity," said Ryan Pinto, Research Analyst, Frost & Sullivan. "These technologies will open up significant growth opportunities by improving the speed and accuracy of logistics battlefield planning, increasing autonomous functionality of systems, aiding decision-making, lowering overhead costs, and enabling less soldier risk."

(News Shorts continue on page 63)

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UAVs and UGVs Ready to Serve on the Battlefield and Beyond

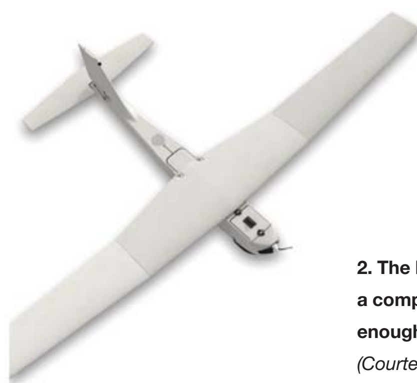
Human forces are relying more on UGVs, UAVs, and other robotic systems to perform critical and dangerous tasks plus serve as intelligent machine partners.

MACHINES NO LONGER require the press of a button to start the power, especially for military missions. Autonomy is coming rapidly to robots and unmanned machines for military applications. They come in the forms of unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs) that can function without an operator, with the aid of artificial intelligence (AI) and environmental sensors. Significant investments by governments on behalf of military robotic applications are literally driving autonomous robotic technologies full speed ahead toward the vision of a battlefield where humans and machines team as partners.

Robots and unmanned vehicles, which have been part of the military landscape for some time, are increasingly used by all four branches of the U.S. military as well as by military forces around the world. Advances in electronic hardware and software support a trend of greater autonomy in these machines, making them more independent from the humans who create them. Military requirements for reduced size, weight, and power (SWaP) also make UAVs, UGVs, and ground robots smaller and lighter.

However, some of the more significant innovations are coming in the area of power, and finding ways, for example, to enable a drone to fly longer and gather more surveillance data without a recharge. The U.S. Department of Defense (DoD) categorizes UAV or UAS sizes into three groups, with the smallest vehicles in Group 1 and the largest called Group 3 vehicles.

1. The Predator XP is one of the better-known military UAVs, adding functionality over time as it evolves with technology. *(Courtesy of General Atomics Aeronautical Systems)*



2. The Puma 3 AE is a compact UAV small enough to launch by hand. *(Courtesy of AeroVironment)*

UAVs: PREDATORS, PUMAS, RAVENS, AND MORE

Unmanned aircraft that are not fully autonomous may not have a pilot on board, but they rely on a human pilot for remote control. As an example, the Predator line of remotely piloted aircraft (RPA) from General Atomics Aeronautical Systems (GA-ASI, www.ga.com) started with the RQ-1 Predator first flown in 1995 by the U.S. Air Force. One of the best-known military UAVs, it has evolved to the much more advanced Predator XP used by U.S. armed forces and licensed for use by allied armed forces around the world.

This latest version of the compact aircraft *(Fig. 1)* features an automatic takeoff and landing system (ATLS) so that the RPA can be launched and recovered without an operator in proximity. With its high-speed line-of-sight (LOS) and non-line-of-sight (NLOS) communication links, it can transfer data quickly from electro-optical (EO) and infrared (IR) cameras as well as many other sensors onboard the aircraft.

The Predator XP has 35-h flight endurance and can ascend to 25,000 ft. In addition, it incorporates a Lynx synthetic-aperture radar (SAR) for wide-area scanning under all weather conditions. Also onboard is a ground moving target indicator (MTI) for locating moving ground vehicles (including UGVs) and a maritime wide-area search (MWAS) mode for coastal surveillance and other maritime missions. The Predator XP flies with an automatic identification system (AIS) for identifying maritime vehicles. The company also makes the Raven, among the smallest of UAVs used by U.S. armed forces.

3. The Marlin is an autonomous underwater vehicle capable of performing inspections 1000 ft. beneath the surface of the water. *(Courtesy of Lockheed Martin)*

4. The MQ-25 UAV is being developed for the U.S. Navy for autonomous in-air refueling missions. *(Courtesy of The Boeing Co.)*

As UAVs are built smaller, they maintain the sensor capabilities of larger aircraft, including multiple cameras and radar systems. They often serve as robotic companions for surveillance and reconnaissance operations, keeping human warriors from dangerous situations. Among these smaller UAVs, the Puma 3 All Environment (AE) aircraft from AeroVironment *(www.avinc.com)* is designed for hand or (as an option) rail launching and manual or autonomous landing *(Fig. 2)*. It has a 4.6-ft. (1.4-m) length and a 9.2-ft. (2.8-m) wingspan and weighs only 15 lb. (6.8 kg).

Generally, designing these robotic systems according to SWaP requirements helps save power. In this case, the miniature UAV uses power efficiently but trades some flight time to work with a relatively small battery pack. With a rechargeable lithium-based battery pack, the Puma 3 AE has a maximum flight time of 2.5 h and can reach altitudes of 300 to 500 ft. The UAV's wireless communications range is 20 km when operating with its standard antenna and as much as 60 km with an optional long-range tactical antenna (LRTA).

The company recently received a fixed-price contract exceeding $5 million for Puma 3 AE systems and support equipment for U.S. Border Patrol, to assist U.S. border patrol agents with remote surveillance. The award was made on behalf of the U.S. Border Patrol, part of the U.S. Customs and Border Protection. Use of the small UAV represents a much more cost-effective solution with greater area coverage than the same size contract for fewer, larger vehicles.

The RQ-11B Raven from AeroVironment is one of the U.S. Army's most widely used UAVs. The hand-launched vehicle is a mere 3 ft. long with a 4.5 ft. wingspan. With a weight of only 4.2 lbs., its payload includes EO and IR cameras with an IR illuminator for night missions. It has flight times of 60 to 90 min. using rechargeable batteries and can transmit images to an operator at LOS distances as far as 10 km for reliable surveillance missions. It can be operated manually or autonomously, with on-board GPS guidance. The RQ-11B flies at altitudes of 100 to 500 ft.

Long-time supplier of unmanned aerial systems (UAS) Lockheed Martin Corp. *(www.lockheedmartin.com)* provides both large and small unmanned systems, from large Warrior, Pioneer, Shadow, Eagle Eye, and Scout systems to smaller UAS vehicles like the Stalker eXtended Endurance (XE), which is launchable by rail or bungee. The Stalker can be powered by a solid oxide fuel cell or rechargeable battery for flight times of 8 h or more. The UAV only weighs 24 lb. but can carry payloads as large as 5.5 lb. Even with a relatively short 12-ft. wingspan, this UAS achieves altitudes to 12,000 ft.

The firm also developed an autonomous underwater vehicle (AUV)—the Marlin—for civilian and military applications *(Fig. 3)*. With underwater control capability to 1000 ft. below the surface, the AUV is designed to inspect subsurface structures without putting human divers at risk. It carries a payload capable of performing high-resolution underwater scans that can be transformed into three-dimensional (3D) models.

As part of an $805 million 2018 contract, Boeing *(www.boeing.com)* is developing the MQ-25 UAV for the U.S. Navy *(Fig. 4)*. Flown from an aircraft carrier, it provides in-flight refueling capability for manned aircraft. The company recently completed the first test flight of the UAV with the U.S. Navy; the MQ-25 completed an autonomous taxi and takeoff and flew a programmed route. The flight of this first test vehicle (T1) comes about two years before the Navy is expected to receive the first of four operational MQ-25s. The refueler will provide the capability to autonomously extend the range of combat strike fighter jets, such as the F-35C, the EA-18G Growler, and the F/A-18 Super Hornet.

ON THE GROUND

UGVs were initially developed to help ground forces in transferring heavy equipment. Over time, they have evolved into more tactical vehicles, assisting on surveillance and in search-and-destroy missions for IEDs. The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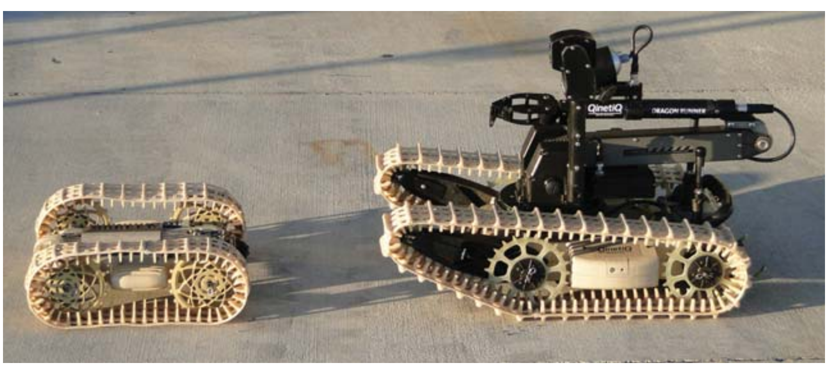
Titan UGV *(Fig. 5)*, developed by QinetiQ North America *(www.qinetiq-na.com)* and Milrem Robotics *(www.milremrobotics.com)*, is an innovative modular UGV that can handle multiple missions, such as rescue, transport, and reconnaissance, and can be readily reconfigured when added or different functionality is needed.

Based on Milrem's tracked hybrid modular infantry system (THeMIS), the Titan is 79 in. long and 83 in. wide. It weighs 2000 lbs. and can carry a maximum payload of 1500 lbs. The vehicle operates in manned and unmanned modes and handles as many as eight cameras, including optical, thermal, and IR devices. The UGV is controlled by the QuinetiQ tactical robotic controller (TRC) and robotic application kit (RAK) for autonomous operation.

Even smaller, the Dragon Runner 10 (DR-10) can be carried to a mission site *(Fig. 6)*. The UGV provides situational awareness of a site to a remote operator with an easy-to-use controller. Developed by QinetiQ North America, the durable robot weighs only 10 lbs. but includes day and night cameras and communications transceivers to enable operators to remain at a safe distance. It's fully capable of delivering remote sensors and placing counter-IED charges and fits well into the U.S. Army's interest in extended mapping of tunnels.

5. The Titan is a modular UGV that can be reconfigured as mission requirements change.
(Courtesy of QinetiQ North America)



6. The Dragon Runner 10 (DR-10) is a UGV light enough (10 lbs.) to be carried in a backpack.
(Courtesy of QinetiQ North America)

The DR-10 ground robot is typical of the UGV designs being pursued by the U.S. Army Combat Capabilities Development Command's Army Research Laboratory (ARL) and partners such as NASA's Jet Propulsion Laboratory (JPL) and Carnegie Mellon University. The ARL's Robotics Collaborative Technology Alliance (RCTA) is involved in developing autonomous methods that support manned and unmanned ground robots and research for the development of future combat ground vehicles. As part of the 2019 Army Modernization Strategy (AMS), near-term goals include neutralizing IEDs by means of a remote armament system (RAS), a defensive approach that can be applied in open battlefields as well as urban areas.

The U.S. Marines have long valued the operating speed and flexibility of the Hunter wheeled offload logistics follower (WOLF) from HDT Global *(www.hdtglobal.com)*. Originally developed for explosive ordnance disposal, the Hunter WOLF combines a 1000-lb. payload with the dexterity of its Adroit robotic arms for precise handling of objects, such as IEDs. The 6 × 6 wheeled ground robot features an electric-hybrid power train (including internal fuel for an electric generator) with a running time of 96 h. It has a range of 100 miles (160 km) and can even ford water levels as high as 24 in.

As the trends indicate, military robotic systems are growing smaller and smarter, inviting slogans from some of the UAV/UGV suppliers about the partnerships of man and machine on the battlefield. These systems can make the battlefield safer for humans, but their values extend much further. Robotic systems are being used around the world for public safety, for fighting fires, even for delivering medicine to patients in remote areas. Robots are earning their places alongside humans and, with the increasing use of AI, will learn to do even more. de

PRODUCT FEATURE

JACK BROWNE | Technical Contributor

EW Simulators Mimic EM Threats

This combination of wideband signal generators, flexible hardware signal adapters, and simulation software can emulate electronic-warfare environments with thousands of EM emitters.

ELECTRONIC-WARFARE (EW) threat simulators provide the means of reproducing the complex electromagnetic (EM) environments common to the battlefield, typically combining voice and data communications streams, radar signals, and jamming signals. For any kind of new application, such as testing radar warning receivers (RWRs) or EW countermeasures systems, to operate successfully in such a hostile environment, it must be able to withstand this barrage of other signals.

First, though, the application must pass a series of performance tests, and to do so, those test signal environments must be recreated. Fortunately, a two-part EW threat simulator from Keysight Technologies *(www.keysight.com)* provides the solution, combining hardware adapters for wideband vector signal generators and powerful simulation software to duplicate the complex pulsed and modulated signals found in EW signal threat environments.

Starting with the sources, the N5194A UXG agile vector adapter is designed for use with the N5193A UXG agile signal generator. The combo delivers extended frequency coverage of 10 MHz to 44 GHz. with fast frequency, amplitude, phase hopping capabilities *(Fig. 1)*.

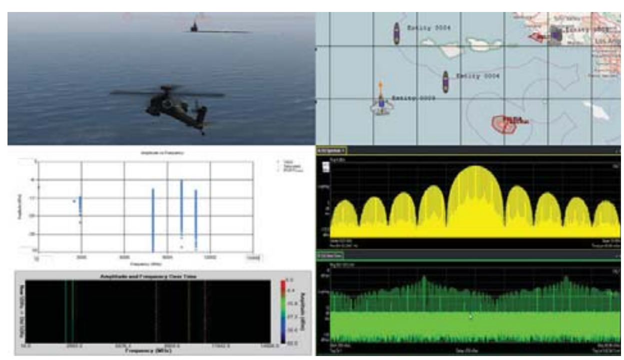
For the N5194A with the N5193A configured as the local oscillator (LO), switching transition times are in the 190- to 250-ns range in narrowband mode with 3-µs latency. In wideband mode, the transition times are typically 170 to 220 ns with 2.5-µs latency. Transition times slow a bit in internal LO mode, typically 470 to 740 ns with 3.5-µs latency.

For cases that do not require fast switching speeds, the model N5192A vector adapter is designed for use with the model N5191A UXG agile signal generator and provides frequency coverage of 10 MHz to 20 GHz with 101-µs switching transition times in external LO mode. Both vector adapters derive frequency accuracy and stability from an external 6-GHz, 50-Ω reference oscillator provided by the N5193A/N5191A sources. The signal sources are based on direct digital synthesis (DDS).

No matter the operating mode or configuration, the agile vector signal generators and adapters deliver outstanding frequency and phase stability. The CW frequency can be tuned with 0.001-Hz resolution while phase offsets are adjustable in 0.1-deg. increments. Maximum signal amplitude is +1 dBm or better across the full frequency range in external LO mode and −2 dBm or better across the full frequency range in internal LO mode. The specified power is +3 dBm from 50 MHz to 18 GHz in either LO mode, with available power of +4 dBm or more. Power can be set with 0.01-dB resolution.

As expected for sources equipped for EW and ECM duties, both adapters/generators provide fast switching speeds from pulse to pulse or frequency to frequency. When generating multiple signals, such as the wave fronts produced by phased-array antennas or multiport angle-of-arrival (AoA) simulations, multiple UXG agile vector adapters can be synchronized together with one UXG agile signal generator. In such a setup, one of the UXG vector adapter units is configured as the LO controller.

1. The combination of the model N5194A UXG agile vector adapter works with the model N5193A UXG agile signal generator and additional software to emulate multi-emitter threat signal environments from 10 MHz to 40 GHz. *(Courtesy of Keysight Technologies)*



2. Powerful software tools are used with the vector signal generators and adapters to simulate electronic battlefields. *(Courtesy of Keysight Technologies)*

The sources can operate in standard vector mode (sampling at 250 Msamples/s) and, as an option, in wideband vector mode (sampling at 2 Gsamples/s), with slightly faster transition times in wideband mode. CW power can be set as low as –120 dBm with the aid of a step attenuator that ranges from 0 to 65 dB in 5-dB steps. The CW output power of both sources is linear for most power levels. At all frequencies, amplitude accuracy is no worse than ±2.5 dB and typically ±0.5 dB when using an external LO. It's no worse than ±3.0 dB and typically ±0.6 dB when using an internal LO.

SURVEYING SPECTRAL PURITY

Signals from the agile vector sources are as clean as they are quick, with low harmonics and spurious contributions and low phase noise. For units working with an internal LO, sampling at 250 Msamples/s (narrowband mode), harmonics are –30 dBc or better for fundamental-frequency signals from 50 MHz to 4 GHz at an amplitude of –10 dBm and –63 dBc or better with fundamentals from 4 to 20 GHz at –10 dBm. For signal sources in external LO mode and 2 Gsamples/s, the harmonic levels are –24 dBc or better for fundamental signals from 50 MHz to 4 GHz at –10 dBm and –63 dBc or better for fundamental signals from 4 to 20 GHz at –10 dBm.

> Signals from the agile vector sources are as clean as they are quick, with low harmonics and spurious contributions and low phase noise.

Non-harmonic spurious content depends on internal or external LO operating modes. For example, for operation in standard vector mode (250 Msamples/s) with an internal LO, the line-related spurious levels are –69 dBc offset 300 Hz or less from carriers 50 MHz to just under 2.5 GHz, –45 dBc offset 300 Hz or less from carriers 2.5 GHz to just below 18 GHz, and –49 dBc at offsets of 10 kHz or more from carriers of 18 to 20 GHz.

With an external LO in standard vector mode, spurious levels are –53 dBc or better at offsets of 300 Hz or less from carriers of 50 MHz to just less than 12.5 GHz. And they are –50 dBc or better at offsets of 300 Hz or less from carriers of

12.5 through 20 GHz, with spurious levels dropping further for offsets further from the carrier.

Whether with internal or external LO, the sources maintain excellent frequency stability and low phase noise throughout the wide frequency ranges. With an internal LO, at a 1-GHz carrier, the phase noise is –132 dBc/Hz or better offset 10 kHz from the carrier and drops to –145 dBc/Hz or better offset 1 MHz from the carrier. Even at a 20-GHz carrier, the phase noise remains low, –113 dBc/Hz or less at a 10-kHz offset and –125 dBc/Hz or better at a 1-MHz offset. In external LO mode, the phase noise is –132 dBc/Hz offset 10 kHz from a 1-GHz carrier and –145 dBc/Hz offset 1 MHz from the same carrier. For a 20-GHz carrier in external LO mode, the phase noise is –106 dBc/Hz offset 10 kHz from the carrier and –117 dBc/Hz offset 1 MHz from the carrier.

THE SIMULATION SIDE

By operating these vector signal sources and adapters with the control possible using commercial-off-the-shelf (COTS) modeling software packages like Keysight's Z9500A Simulation View software and N7660C Signal Studio for Multi-Emitter Scenario Generation (MSEG) software, the hardware/software combination enables full-spectrum modeling with dynamic scenario control to adapt to changing signal environments. The company also provides UXG system integration with automated multi-source and system-level calibration software.

The N7660C MESG and Z9500A Simulation View software are capable of multi-emitter threat simulations *(Fig. 2)*. They can simulate an electronic battlefield with thousands of emitters including advanced pulse-modulated or chirped signal waveforms and even perform AoA analysis on signals used in direction-finding (DF) applications.

The Z9500A Simulation View software uses real-time pulse-descriptor-word (PDW) streaming for creating radar signals. The Z9500A's open architecture also makes it possible to work with other software tools to create realistic threat signal simulations based on a user's database of models and threat scenarios. In addition to Keysight's simulation software tools, customers have the flexibility to use their own software tools to create PDW-based scenarios with the UXG agile signal generators. de

KEYSIGHT TECHNOLOGIES Inc., 1400 Fountaingrove Pkwy., Santa Rosa, CA 95403-1738; www.keysight.com.

JACK BROWNE | Technical Contributor

Custom Solutions Connect in Harsh Environments

When standard connectors don't fit, these connectors can be customized to meet the mechanical/electrical requirements of the most demanding military and commercial applications.

CABLES AND CONNECTORS are often an afterthought—until they fail. Whether as a loss of power, phase distortion in a receiver, or irregular signal transfers, seasoned system designers have learned the importance of making the best connections possible, which can be difficult at times depending on the mechanical and electrical configuration of a radar, electronic warfare (EW), or electronic countermeasures (ECM) systems. However, at least one source—Connectronics Corp. *(www.connectronicscorp.com)*—offers custom cables and connectors for high-voltage, high-current, and even underwater applications targeting military, industrial, and commercial markets.

For many systems, standard high-voltage and high-current connectors will provide the performance levels needed to meet electronic defense specifications. For example, the Dual HVL series high-voltage connectors are available in panel-mount or in-line configurations for maximum voltages from 10 to 20 kV and for use at altitudes to 70,000 ft. The corona-resistant, radiation-resistant connectors handle operating temperatures from −55 to +125°C. The connectors can be assembled at the factory or in the field.

For high-voltage applications through 15 kV dc where corona effects are a concern, the company's CMC-715 Series high-voltage connectors *(Fig. 1)* incorporate tapered interfaces designed for high altitudes (to 70,000 ft.) and high temperatures (from −55 to +125°C). They can be used with AWG-16 through AWG-24 stranded wire, with knurled- or hex-nut threaded coupling, and supplied as parts of kits for customer assembly or terminated at the factory, complete with straight or right-angle overmolding.

1. High-voltage connectors like the CMC-715 devices can be used to 15 kV dc at altitudes to 70,000 ft. and temperatures to +125°C.

CHANNELING CURRENT

High-current connectors include the Safety Lock Series for safe and reliable interconnections, available in 200- and 400-A versions for three-phase service use at voltages to 600 V. The single-pin connectors employ a ground configuration that makes it difficult to improperly connect any power until the ground and neutral connections are made. For safety, including in emergency-service applications, ground and neutral connections cannot be disconnected until all other power lines are disconnected.

These high-current connectors can be installed in stationary panel boards (with a standard size of 3.5 × 19.0 in. for input and output boards) for rack-mounted setups or used in the field. The connectors feature a large self-wiping contact area and silver-plated construction. They can be assembled with standard tools and require no special maintenance. The UL-listed and patent-protected safety lock system features machined aluminum shells with a corrosion-resistant anodized finish. The connectors are designed for operating temperatures from −65 to +125°C and for altitude to 10,000 ft.

For applications requiring custom connectors and/or cable assemblies, the firm offers examples of its engineering and in-house test capabilities in the forms of specialized connectors, such as O-ring-sealed, stainless-steel-overmolded connectors for underwater use, and its hermetic connectors *(Fig. 2)*. Hermetic connectors, for example, are 100% helium leak tested prior to shipping.

2. Specialized connectors such as these hermetic options are well-suited for high-vacuum and high-current aerospace systems.

Specialized and custom connectors can be developed with thermocouple functions for currents beyond 1 kA, for low-outgassing applications, and for temperatures as high as +250°C in the most demanding applications (e.g., in x-ray equipment and nuclear systems). The company backs all of its designs with extensive engineering experience, a well-equipped CNC machining facility, and well-stocked test laboratory, along with the people who know how to use those instruments. de

CONNECTRONICS CORP., 2745 Avon-dale Ave., Toledo, OH 43607-3732; (800) 965-0020, (419) 537-0007, www.connectronicscorp.com.

JACK BROWNE | Technical Contributor

Signal Recorder Integrates RF Tuner

The RTR 2654 RF Sentinel Intelligent Signal Scanning system automatically finds and records signals within 500-MHz swaths of bandwidth from 800 MHz to 26.5 GHz.

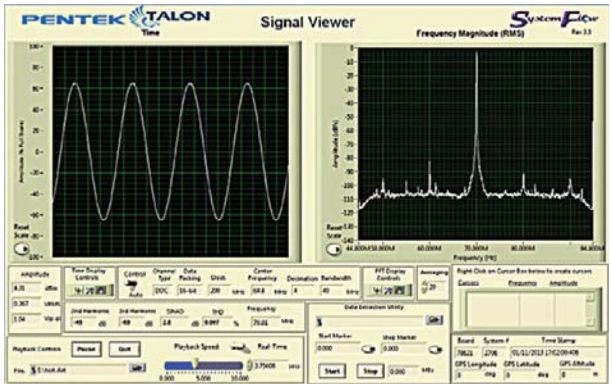
SIGNAL MONITORING FOR signal intelligence (SIGINT) and communications intelligence (COMINT) usually requires a rack of instruments including a wideband receiver and a signal recorder. Rarely do the two instruments come in the same box, except in the case of the Talon RTR 2654 Sentinel Intelligent Signal Scanning system from Pentek *(www.pentek.com)*. It combines a microwave tuner—with a frequency range of 0.8 to 26.5 GHz and bandwidths as wide as 500 MHz—and a digital recorder. With the company's Sentinel intelligent scanning software, it can automatically scan across that frequency range and record signals for further consideration.

The combination tuner/recorder features a modular architecture, enabling it to pack so much functionality within a relatively compact package *(Fig. 1)*. The Talon RTR 2654 Sentinel system uses a Pentek model 78141 Jade transceiver module as the data-acquisition subsystem. It's a popular building block for software-defined radios (SDRs).

With its digital upconverters (DUCs) and digital downconverters (DDCs), the system is capable of processing 6.4 GHz in a single channel or two 3.2-GHz channels. The transceiver's front-end section feeds a maximum 500-MHz intermediate-frequency (IF) output to one of two 3.2-Gsample/s 12-b analog-to-digital converters (ADCs) running at 2.8 Gsamples/s. The 12-b ADCs yield a signal-to-noise ratio (SNR) of better than 57 dB and a spurious-free dynamic range (SFDR) of 72 dB across the full frequency range. A DDC controls spectrum analysis in steps of 140, 280, and 500 MHz. Once a signal of interest is detected, it can be rescanned and stored. Signal searches can be performed by manual control or under computer control of easy-to-use software.

Contiguous bandwidth scans can be run where the stop frequency of swept frequency band is the start frequency of the next swept frequency band. The transceiver will monitor and perform signal detection over any portion of bandwidth, up to 500 MHz wide, within its total bandwidth. Signals can be detected according to different search parameters, such as signal amplitude threshold levels (within the dynamic range of the receiver). Once found, it's possible to record a signal for further analysis, with as much as 245 TB of on-board solid-state memory for long-term scanning, analysis, and storage of signal trends and history.

1. The RTR 2654 RF Sentinel Intelligent Signal Scanning system automatically tunes and records signals within 500-MHz swaths of bandwidth from 800 MHz to 26.5 GHz. *(Courtesy of Pentek Inc.)*

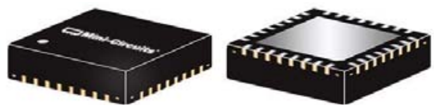


2. SystemFlow software works with the Talon recorder for flexible analysis of captured signals. *(Courtesy of Pentek Inc.)*

The Talon RTR 2654 Sentinel is based on a Microsoft Windows workstation with a Core i7 microprocessor from Intel Corp., as well as graphical-user-interface (GUI) and application programming interface (API) software. System control and turnkey operation are provided by an enhanced version of Pentek's SystemFlow software, which includes intelligent scanning and integrated control of the RF tuner and optional RF upconverter. The software has a flexible GUI with mouse-controlled point-and-click configuration and can store custom configurations for fast, single-click setups.

The SystemFlow software *(Fig. 2)* and hardware also support a virtual oscilloscope, spectrum analyzer, and spectrogram for signal monitoring. In addition, commercial analysis software such as MATLAB from MathWorks *(www.mathworks.com)* can be installed on a Talon 2654 system to increase the analysis power. Data files for captured signals are recorded in the Windows native new technology file system (NTFS) file format to simplify data management. SystemFlow software is an integrated component of every Talon recorder; it's not available as standalone software.

PENTEK INC., One Park Way, Upper Saddle River, NJ 07458; (201) 818-5900, FAX: (201) 818-5904, E-mail: sales@pentek.com, www.pentek.com.



MMIC Power Splitter/Combiner Channels DC to 18 GHz

MINI-CIRCUITS' MODEL EP4RKU+ is a four-way 0-deg. power splitter/combiner with broadband frequency range of dc to 18 GHz. Insertion loss above the 6-dB four-way power split is extremely low, typically 4.2 dB from dc to 4 GHz and only 3.4 dB from 4 to 18 GHz. The tiny splitter/combiner handles maximum full-band power of 0.6 W as a divider, and as much as 0.6 W per port as a combiner. The 50-Ω RoHS-compliant component is fabricated with GaAs MMIC technology; the resistive/reactive design extends the EP power splitter/combiner series to dc. The splitter/combiner is supplied in a surface-mount QFN package measuring just 5 × 5 × 1 mm. Despite the small size, typical isolation between ports is 20 dB at 9 GHz. With outstanding amplitude and phase unbalance, the power splitter/combiner is a good fit for a wide range of wireless communications and test-and-measurement applications. It's designed for operating temperatures of –55 to +105°C.

MINI-CIRCUITS

P.O. Box 350166, Brooklyn, NY 11235-0003; (718) 934-4500, https://www.minicircuits.com/WebStore/dashboard.html?model=EP4RKU%2B

Cable Assembles Built for Space

WELL-SUITED FOR high-power, high-density applications from dc through 40 GHz, the GORE Spaceflight microwave assemblies are coaxial cable assemblies with a wide range of connector options, including SMA, SMP, 2.92-mm, and TNC connectors. Cable diameters range from 0.047 in. (1.2 mm) to 0.320 in. (8.1 mm). Qualified for use by the European Space Agency (ESA), Spaceflight cable assemblies feature high radiation resistance, low insertion loss, and low passive intermodulation (PIM). They also provide excellent shielding effectiveness with good phase stability and can handle extremely broad operating temperature ranges from –155 to +150°C.

W.L. GORE & ASSOCIATES (UK) LTD.

Mariner Dr., Dundee Technology Park, Dundee, DD2 1JA, Scotland; +44 1382 561511, FAX: +44 1382 561007, www.gore.com

High-Power Fixed Pads Attenuate to 18 GHz

HIGH-FREQUENCY FIXED ATTENUATORS feature attenuation values of 3, 6, 10, 20, 30, and 40 dB at frequencies from dc to 18 GHz and power levels of 10, 25, 50, and 100 W. With VSWR levels as low as 1.20:1, the 10- and 25-W attenuators provide bidirectional operation while the 50- and 100-W attenuators support directional operation. They are rated for peak power to 500 W and come with in-series connector gender interfaces as well as male-female configurations with both SMA and Type-N coaxial connectors. The attenuators are constructed with black anodized aluminum heatsink bodies and designed with large cooling fins that aid in heat dissipation at high temperatures.

PASTERNACK ENTERPRISES INC., AN INFINITE ELECTRONICS BRAND

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

Danes Look to Safran for Enhanced Night Vision

(News Shorts continued from page 46)

SEEKING EXTENDED OPTICAL RANGES, Denmark's armed forces will be using JIM Compact infrared (IR) binoculars from Safran Electronics & Defense (www.safran-electronics-defense.com). The long-range thermal imagers were selected for the country's Association of the U.S. Army (AUSA) by the NATO Support and Procurement Agency.

IR binoculars provide ground troops with enhanced night vision as well as wireless communications and laser range detection. *(Courtesy of Safran Electronics & Defense)*

The IR binoculars, developed through the guidance of size, weight, and power (SWaP) initiatives, weigh less than 2 kg with battery. They are ideal for day and night operations and are equipped for multiple functions, including wireless communications. The basic portable IR binocular unit combines a high-resolution cooled IR channel, a television channel, a laser pointer, a laser range finder, a low-level light channel, a digital magnetic compass, and a Global Positioning System (GPS) receiver in one compact unit.

The handheld optronics system is designed for a wide range of applications in all weather conditions, including target acquisition, fire correction, and joint tactical air controller missions. The IR binoculars are already in use by nine different NATO forces. Per this NATO contract, several dozen of the binoculars will be delivered to the Danish military by the end of 2019. ■

Dutch Army Tracks Containers with IoT

DEVICES USING INTERNET OF THINGS (IOT) technology are often associated with commercial wireless applications in 5G networks, but the Dutch Army is showing that IoT can prove battleworthy as well. Defense contractor Marshall Aerospace and Defence Group (Marshall ADG), as part of a contract with the Dutch Army for ruggedized containers and services for those containers, will supply containers with secure IoT capabilities based on technology from AT&T Business.

When equipped with this IoT technology, Marshall can remotely monitor the location, condition, and temperature of the containers for its end customers, such as the Dutch Army, using wireless communications links with the IoT devices built into the containers *(see figure)*. Monitoring will be simplified and automated thanks to AT&T's control center platforms.

Marshall expects to deliver more than 1,400 of the IoT-connected containers over the next five years. The containers include command and control and medical container systems, workshops, containers with controlled atmospheres, and basic storage units. By having containers accessible using wireless networks with access to the internet, military commanders will know the whereabouts of equipment at any time. The contract was awarded to Marshall by the Dutch Defence Materiel Organisation (DMO) at the end of 2018.

"Being able to track and monitor the containers added another dimension to this important contract for the Dutch Army," said Steve Nokes, Project Director DVOW at Marshall Aerospace and Defence Group. "We are delighted to be delivering these container systems as a result of a rapid development and manufacturing program, and to offer this enhanced service to our customer thanks to the global solution delivered by the team at AT&T." ■

IoT technology in league with wireless networks makes it possible to track the whereabouts of secure military containers around the world. *(Courtesy of Marshall Aerospace and Defence Group)*

JEFF KAHLER | Technical Director, Nuhertz Technologies
www.nuhertz.com

ANDREAS WIEN | Empire Product Manager, IMST
www.imst.com

Antenna 3D Simulator and Optimizer Handles Planar Filter Designs, Too

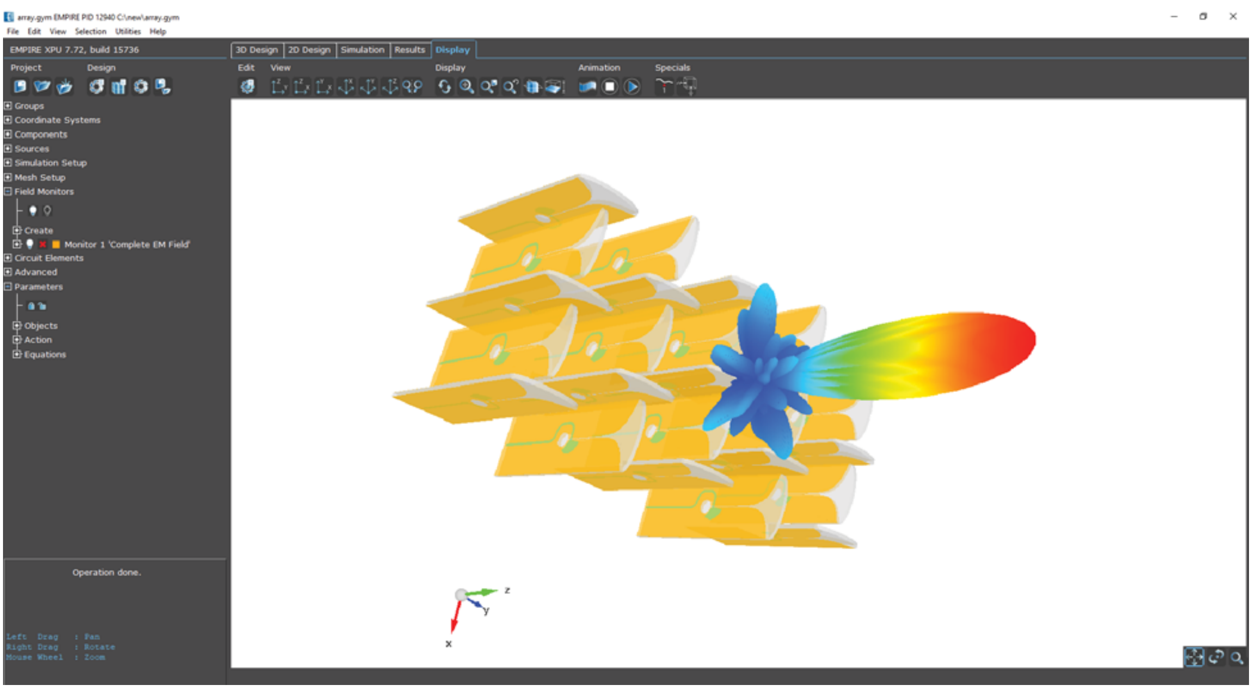
A 3D electromagnetic field solver that focuses on antenna design can also optimize planar filter designs when used in tandem with a separate software tool.

For many years, IMST (*www.imst.com*) has been in the business of producing expert 3D electromagnetic (EM) simulation software. With its Empire XPU (*www.empire.de*) product, IMST emphasizes and focuses on antenna design and optimization. Nuhertz Technologies (*www.nuhertz.com*) has also been around for many years, producing expert filter design software. And with its FilterSolutions tool, the company focuses on accurate 3D planar design and optimization.

Therefore, it seems a natural fit for these two products to work together so that users can take advantage of the best features of both. Specifically, IMST's Empire XPU EM optimization process can be used on planar designs created with Nuhertz's FilterSolutions.

EMPIRE XPU ANTENNA DESIGN OVERVIEW

Empire XPU is an advanced 3D EM field solver based on finite-difference time domain (FDTD) that's been highly



1. This Empire XPU simulation of a Vivaldi antenna array shows the radiation pattern at 12 GHz.

optimized for memory efficiency and performance speeds. It uniquely features an innovative software acceleration that makes it possible to use the complete RAM, achieving performance of up to 22 GCells/s on a dual CPU workstation.

Empire XPU supports a broad range of applications (i.e., RF passive components and circuits, packages, waveguides, and EMC), but its major focus is antennas of all varieties. The geometry and excitation are rapidly set up in a sophisticated graphical user interface (GUI). Expert-level automatic meshing and optimization algorithms guide the user to the final design. Visualization features help the user obtain physical insight into the EM wave phenomena.

FILTERSOLUTIONS PLANAR DESIGN OVERVIEW

The FilterSolutions planar design module rapidly produces circuit-level-optimized planar designs that account for internal lossy and discontinuous parasitic effects. The FilterQuick beginner's design panel is easy to use and understand, providing visual aids to help new users get started. For experienced users, an advanced panel delivers full design power in an easy-to-access compact panel.

Planar designs may be exported directly into Empire XPU, including the stackup, layout, and full parameterization needed to tune and optimize all of the relevant layout geometries. The exported design is fully equation-based so that the individual parameters update the entire layout geometry as needed to keep the design coherent.

EMPIRE SETUP FOR ANTENNA 3D SIMULATION

Antenna simulations require the absorption of boundary conditions and space for the reactive near field. Empire XPU automatically creates a suitable environment, depending on the desired frequency range. The model is excited at ports by a time pulse that covers the entire frequency range. S-parameters are obtained after energy has decayed. Monitors record the desired field values for the quantification of typical antenna parameters, such as gain, beam width, or side-lobe levels. Antenna arrays can be excited simultaneously with amplitude taper and broadband phase shift (*Fig. 1*) or sequentially to obtain coupling parameters.

EMPIRE SETUP FOR ANTENNA 3D OPTIMIZATION

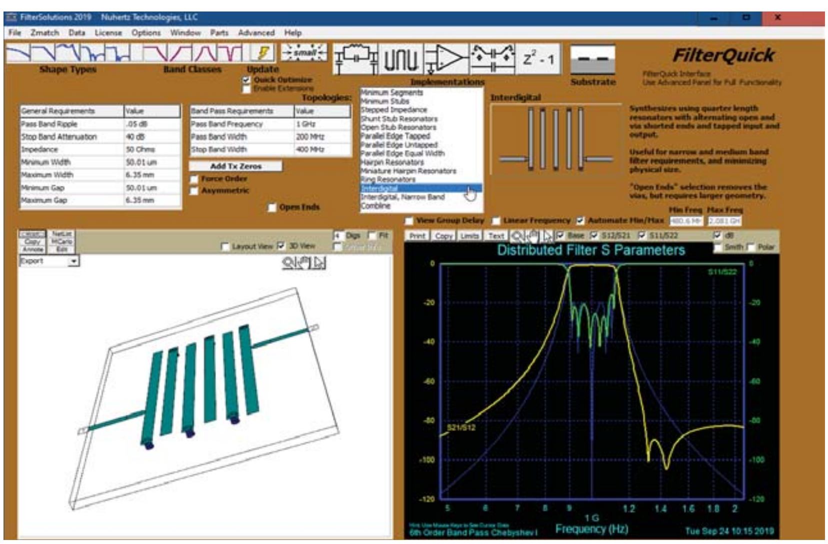
Initial antenna designs are available as built-in templates or can be imported from other CAD sources. It's also possible to create the structure from scratch or with the aid of scripting. The geometry and material properties can be defined as variables and different optimization algorithms can be applied to find the best parameter set. Different result sources and goal functions may be applied in the error function, which the software then tries to minimize. Because the optimization requires running many variable combinations, Empire XPU can use job distribution and parallel execution on remote servers during the process.

EMPIRE SCRIPTING OVERVIEW

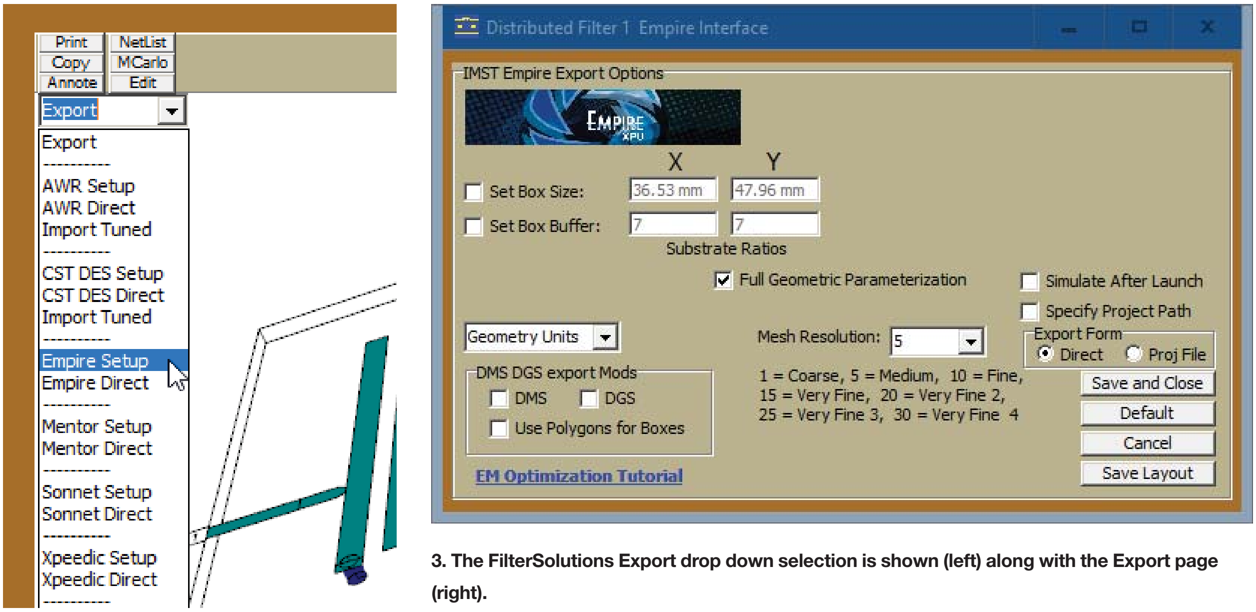
With the aid of the Python programming language, the model is able to be set up partially or completely with the aid of scripting. Even parametric models, equations, and optimization goals can be defined by scripts to be used in a subsequent optimization process. It's also possible to run simulations completely in the background on the local computer or remote machines. Furthermore, scripting can be used for post-processing derived results to be applied in the optimization goal functions.

FILTERSOLUTIONS PLANAR DESIGN CAPABILITIES

FilterSolutions produces a great deal of topologies for planar designs with easy to-access form entries for design requirements. The FilterQuick design panel tabulates the topology options in an easy-to-use selection format, along with a sample pictorial graphic and textual feedback, so that new users will know exactly what they are selecting.



2. A simple interdigital design is depicted in this FilterQuick design panel.



3. The FilterSolutions Export drop down selection is shown (left) along with the Export page (right).

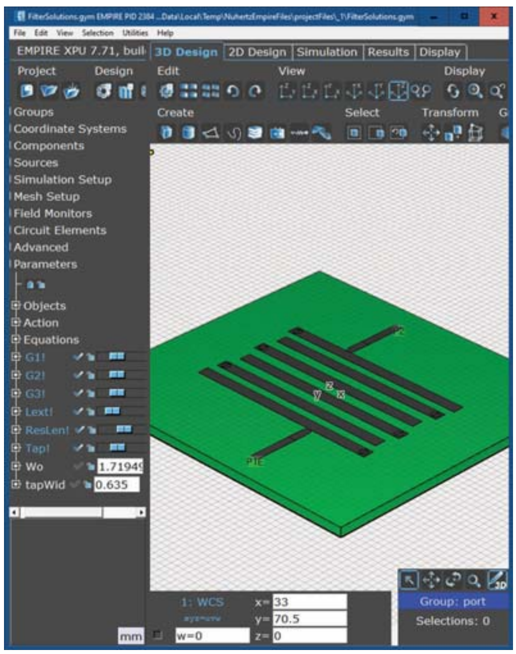
Designs may be optionally optimized for circuits-simulation response by selecting "Quick Optimize." The circuits simulation accounts for lossy and discontinuous parasitic effects. The filter topology display may be selected to be a schematic with geometric dimensions, a planar layout view, or a 3D view. *Figure 2* shows a simple interdigital design with default requirements entries, a 3D layout, and S-parameter circuits-simulated results.

FILTERSOLUTIONS DIRECT EXPORTATION INTO EMPIRE

The "Export" dropdown on the upper left is used to export to Empire XPU (*Fig. 3*). Selecting "Setup" will bring up the Empire export panel, while selecting "Direct" will export directly to Empire using previously saved export entries. The Empire export page provides all of the export options available to Empire XPU, including, but not limited to, path, substrate geometry, DMS and DGS defected selections, and simulation speed/accuracy selections.

EMPIRE SIMULATION AND OPTIMIZATION OF FILTERSOLUTIONS PLANAR DESIGNS

The FilterSolutions design export into Empire XPU includes all parameters and equations needed for Empire to apply its 3D EM optimizations capability directly on the exported FilterSolutions planar design. Easy-to-use slider bars may tune any of the exported parameters. All the equations needed to maintain the integrity of the planar design, as well as the tunable parameters, are included in the exported design. *Figure 4* shows the Empire XPU GUI with the exported interdigital filter.



4. This interdigital design was exported from FilterSolutions into Empire XPU.

All the equations needed to maintain the integrity of the planar design, as well as the tunable parameters, are included in the exported design.

3D simulations can be initiated directly on the exported project by selecting "Start Simulations" from the File menu drop down. *Figure 5* shows the 3D EM S-parameter results in the Empire simulation page. It's clear that some EM optimization is desirable for this filter design.

3D EM optimization may be applied with the Simulation Optimization Control. Optimization goals are already

Planar filters and antennas both reside in 3D space, and the fine-tuning of the geometries within that 3D space may optimize planar filters or antennas.

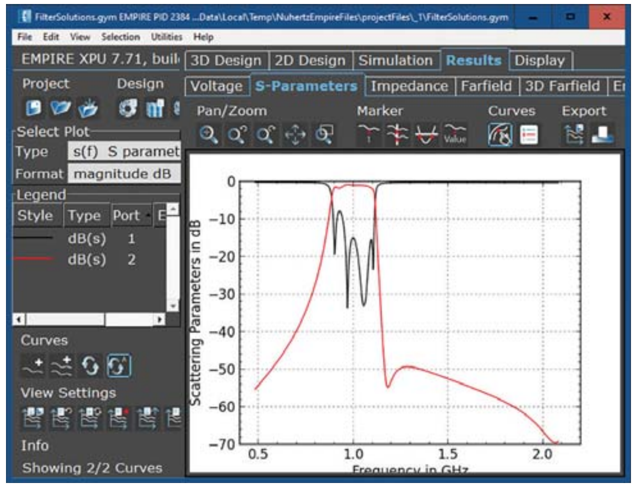
installed in the project, and simply need to be included in the Simulation Optimization goals page. A tutorial in the FilterSolutions Empire Export page provides detailed Empire GUI instructions for the optimization process.

Once the optimization process is configured, users only need to start it and then just sit back and let Empire XPU do the optimization work. After the optimization is complete, the optimized parameters can be copied back into FilterSolutions. *Figure 6* shows the fully optimized Empire XPU 3D EM S-parameter trace.

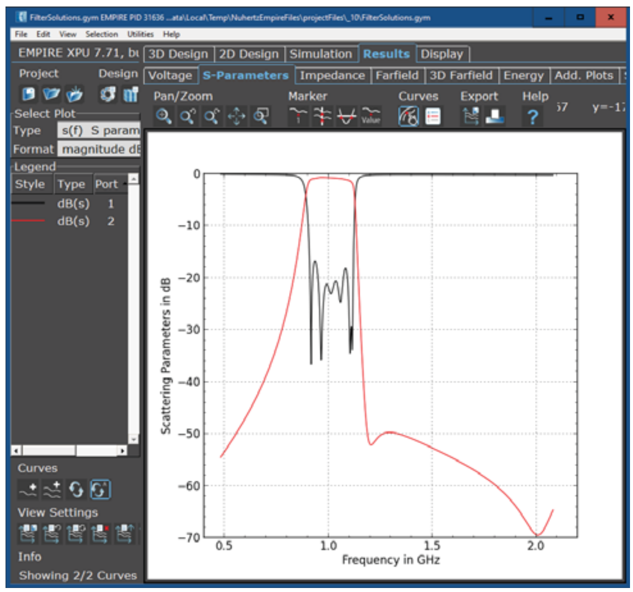
CONCLUSION

This article reveals that even though the raw synthesis of antenna and filter design are dramatically different tasks that require widely differing design skills and tools, finalization of the design process is similar enough whereby the same tools can be used. Planar filters and antennas both reside in 3D space, and the fine-tuning of the geometries within that 3D space may optimize planar filters or antennas. This, in turn, brings to bear Empire XPU's diversity as an EM optimization tool—it can efficiently perform 3D optimizations of planar filter designs as well as 3D antenna designs.

Anyone involved with planar filter design should consider synthesizing their designs with Nuhertz FilterSolutions followed by an easy-to-use direct interface to Empire XPU to finalize the 3D optimization. And, as stated, Empire XPU is a tool that extends beyond planar filters, with the ability to perform 3D EM optimizations of antennas as well. mw



5. These interdigital Empire XPU 3D simulation S-parameter results reveal that some filter optimization is needed.

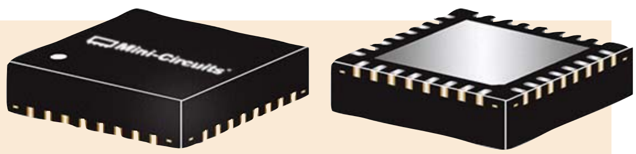


6. Shown are the fully optimized Empire XPU 3D EM S-parameter traces.

SP6T Switch Matrix Commands DC to 40 GHz

MINI-CIRCUITS' MODEL RC-1SP6T-40 is a PC-controlled electromechanical single-pole, six-throw (SP6T) switch matrix for applications from dc to 40 GHz. The rugged unit can handle as much as 5 W signal power during cold switching and is rated for at least 2 million switch cycles with cold switching. The SP6T switch matrix can be controlled with a PC running Windows 98 or later operating system (OS). Graphical-user-interface (GUI) and other support software is available for free download from the Mini-Circuits website. The switch matrix is equipped with 2.92-mm female coaxial connectors on all RF ports as well as USB and Ethernet ports for control connections. It features typical insertion loss of 0.2 dB from dc to 12 GHz, 0.4 dB from 12 to 26 GHz, and 0.7 dB from 26 to 40 GHz. Typical isolation is 90 dB from dc to 12 GHz, 80 dB from 12 to 26 GHz, and 70 dB from 26 to 40 GHz. The 50-Ω switch matrix is designed to run on +24-V dc and at operating temperatures of 0 to +40°C. Typical switching speed is 25 ms and it has a worst-case VSWR of 2.20:1 across the full frequency range. The unit comes in a rugged metal case measuring 5.5 × 6.0 × 2.75 in. (139.70 × 152.40 × 69.85 mm).

MINI-CIRCUITS, P.O. Box 350166, Brooklyn, NY 11235-0003; (718) 934-4500,
https://www.minicircuits.com/WebStore/dashboard.html?model=RC-1SP6T-40



10.7- to 31.0-GHz Power Splitter/Combiner Built with GaAs MMIC Tech

MINI-CIRCUITS' MODEL EP4KA+ is a four-way 0-deg. power splitter/combiner with a wide frequency range of 10.7 to 31.0 GHz. Insertion loss above the 6-dB four-way power split is minimal—typically 0.4 dB from 10.7 to 13.0 GHz, 0.6 dB from 13 to 22 GHz, and 1.1 dB from 22 to 31 GHz. Typical isolation between ports is 13.1 dB from 10.7 to 13.0 GHz, 19.3 dB from 13 to 22 GHz, and 21.5 dB from 22 to 31 GHz. The resistive/reactive design is fabricated with GaAs MMIC technology and supplied in a surface-mount QFN package that measures 5 × 5 × 1 mm. The EP4KA+ can handle as much as 0.6 W input power as a divider and as much as 0.6 W per port as a combiner. The 50-Ω RoHS-compliant power splitter/combiner exhibits low VSWR of 1.40:1 or better at all ports with excellent amplitude and phase unbalance. It has an operating temperature range of –55 to +105°C and is a good match for broadband communications and test applications.

MINI-CIRCUITS, P.O. Box 350166, Brooklyn, NY 11235-0003; (718) 934-4500,
https://www.minicircuits.com/WebStore/dashboard.html?model=EP4KA%2B

MMIC Amplifier Maintains Flat Gain from 50 MHz to 8 GHz

THE PHA-83W+, a high-dynamic-range MMIC amplifier with a broad frequency range of 50 MHz to 8 GHz, runs on a +5- or +9-V dc supply voltage. The amplifier achieves typical gain of 10 dB or better and gain flatness of ±2.8 dB across the full frequency range with a +5-V dc supply. With a +9-V dc supply, typical gain is 14.2 dB with a gain flatness of ±1.4 dB across the full frequency range. The noise figure is typically 3.1 dB or less from 50 to 4,000 MHz and typically 4.7 dB or less across the full frequency range. The miniature 50-Ω amplifier typically delivers +15.9 dBm or more output power at 1-dB compression from 50 to 4,000 MHz, and typically +13.2 dBm or more across the full frequency range. The RoHS-compliant GaAs pHEMT amplifier, which comes in a thermally efficient SOT-89 package, has an operating temperature range of –40 to +85°C.

MINI-CIRCUITS, P.O. Box 350166, Brooklyn, NY 11235-0003; (718) 934-4500,
https://www.minicircuits.com/WebStore/dashboard.html?model=PHA-83W%2B

Frequency Dividers Divide from 2 to 40

A LINE OF FREQUENCY-DIVIDER MODULES consists of 28 different prescaler models. Input frequency coverage spans 0.1 to 20 GHz, while the divide-by ratios range from 2 to 40. The frequency-divider modules come in compact and rugged SMA connectorized packages. Depending on the model, the dividers can handle input power levels ranging from –20 to +15 dBm, with output power levels that range from –6 to +5 dBm. The modules are designed for high reliability, with most models guaranteed to meet MIL-STD-202 environmental test conditions for shock, humidity, vibration, and altitude.

FAIRVIEW MICROWAVE, 301 Leora Ln. Suite 100, Lewisville, TX 75056; (800) 715-4396 or (972) 649-6678, www.fairviewmicrowave.com

Dual-Directional Coupler Spans 10 to 46 GHz

KRYTAR'S MODEL 510046010 is a dual-directional coupler that covers a frequency range of 10 to 46 GHz. The coupler achieves a nominal coupling value of 10 ±1.8 dB along with less than 2.8 dB of insertion loss. The directivity is greater than 10 dB, while maximum VSWR at any port is 1.8:1. The 510046010 is rated for 20 W of average power and 3 kW of peak power. Built with 2.4-mm female connectors, the directional coupler measures 2.24 (L) × 0.40 (W) × 0.62 (H) in. and weighs 2.0 ounces. Operating temperature range is –54 to 85°C.

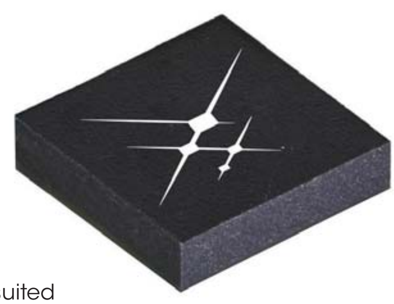
KRYTAR, 1288 Anvilwood Ave., Sunnyvale, CA 94089; (408) 878-1769, www.krytar.com

Lowpass Filter Accepts Signals from DC to 55 GHz

MODEL SCF-55375330-2F2M-L1 is a coaxial lowpass filter with a passband from dc to 55 GHz. The typical passband insertion loss is 1.5 dB, while typical passband return loss is 15 dB. The filter's rejection band ranges from 75 to 110 GHz, with a typical rejection value of 30 dB. The SCF-55375330-2F2M-L1 is built with a male 2.4-mm connector for one port and a female 2.4-mm connector for the other. Other configurations, such as different connectors for the ports, are available under different model numbers.

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

High-Efficiency PA Covers 3,300 to 3,600 MHz



SKYWORKS' SKY66318-11 is a high-efficiency power amplifier (PA) that covers a frequency range of 3,300 to 3,600 MHz. It achieves a wide instantaneous signal bandwidth of 100 MHz. At 3.35 GHz, the PA delivers 36 dB (typical) of gain and +33 dBm of output power at 1-dB compression. Power-added efficiency (PAE) is 20% at an output power level of +28 dBm. On-chip active biasing circuitry is integrated to compensate for PA performance over temperature, voltage, and process variations. The SKY66318-11, which comes in a compact 5- × 5-mm package, operates from a single +5-V dc supply and is well-suited for 4G LTE and 5G NR systems.

SKYWORKS SOLUTIONS, 5221 California Ave., Irvine, CA 92617; (949) 231-3000, www.skyworksinc.com

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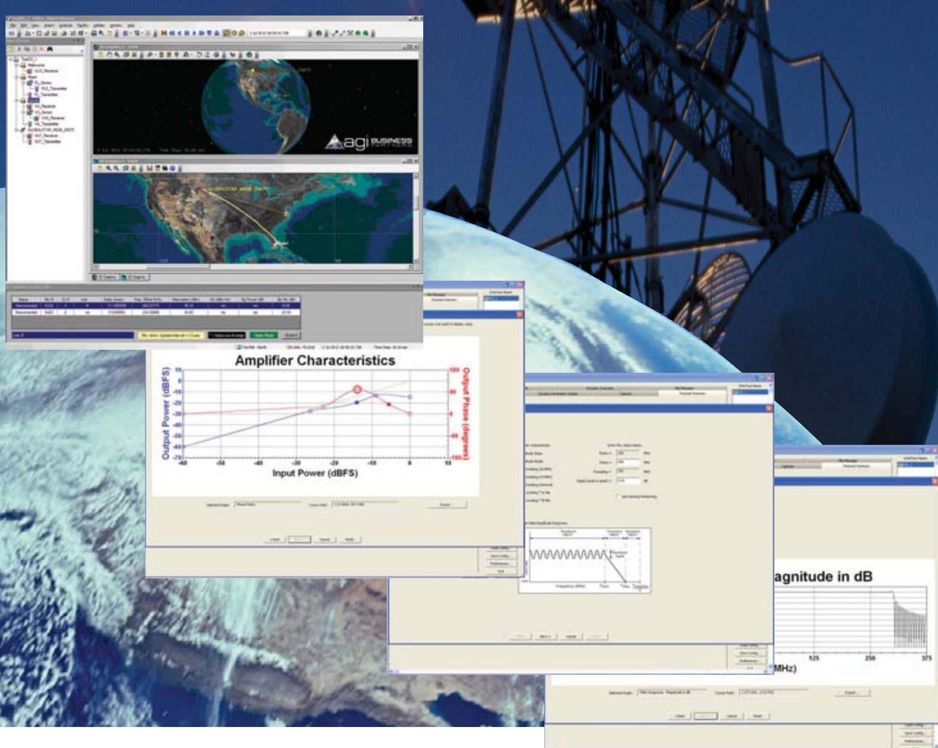

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RF Test Equipment for Wireless Communications

email: info@dbmcorp.com

dBm Corp, Inc
32A Spruce Street ◆ Oakland, NJ 07436
Tel (201) 677-0008 ◆ Fax (201) 677-9444
www.dbmcorp.com