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The Value of Software-Defined Radio Integration Across Industries p31

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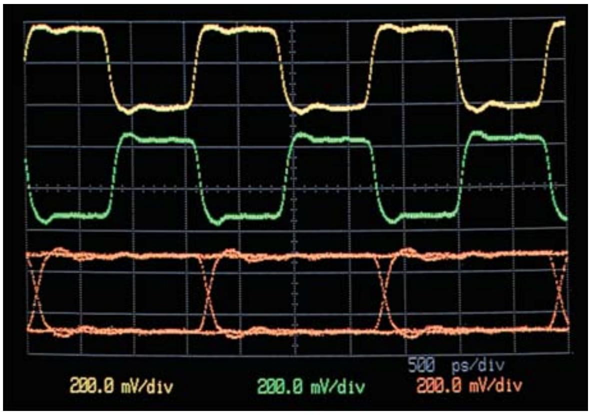

Plot shows complementary clocks and PRBS (opt. 01) outputs at 622.08 Mb/s with LVDS levels. Traces have transition times of 80 ps and jitter less than 1 ps (rms).

The CG635 generates clock signals—flawlessly. The clock signals are fast, clean and accurate, and can be set to standard logic levels.

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October 2020 VOLUME 59, ISSUE 10

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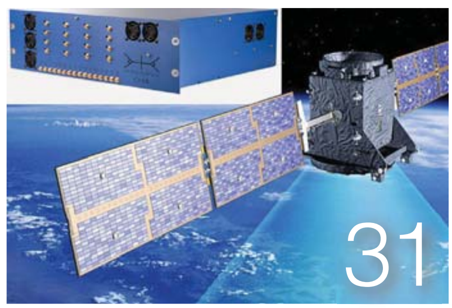
FEATURES



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Editorial

DAVID MALINIAK | Editor

dmaliniak@endeavorb2b.com

Amazon Strides Out to the Sidewalk

Companies like Amazon are so entrenched in our day-to-day affairs that it's hard to remember life before they arrived. Now, the retailing and cloud-computing behemoth wants to extend its wireless tentacles to envelop our homes more fully, and even our yards. Its vision for what it's calling Amazon Sidewalk is a neighborhood network that will use Bluetooth LE and the 900-MHz spectrum to extend the low-bandwidth working range of our wireless devices. And it will help them stay connected even if they stray outside the range of our Wi-Fi routers—even up to 1 km away.

Access to Amazon Sidewalk, expected to launch later in 2020, will initially come through two types of devices: Sidewalk Bridges and Sidewalk-enabled devices. The former will include devices like Ring floodlight and spotlight cameras. The latter, things like smart lights in your driveway, will access the network through Sidewalk Bridges, especially useful if your driveway extends out of Wi-Fi range.

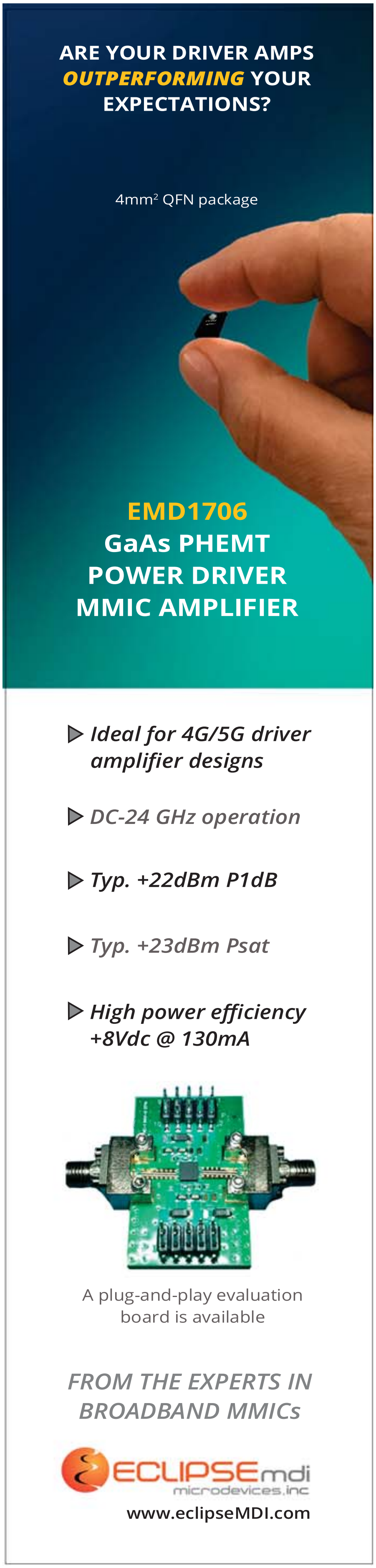
Amazon has already enlisted several IoT silicon vendors to produce the connecting links for Amazon Sidewalk:

- Nordic Semiconductor will engage on the Bluetooth LE side, with its low-power-consumption nRF52 Series and newly released nRF53 Series SoCs providing connectivity. The company will also support the Amazon Common Software (ACS) platform with a device porting kit for its wireless chips, allowing them to be easily and natively integrated into ACS as one of its reference platforms.
- Semtech will contribute expertise on the 900-MHz LoRa front with its long-range, low-power IoT platform. It will extend the range of home networks to connect both outdoor and indoor, low-bandwidth smart-home products, including smart lights, pet trackers, sensors for asset tracking, smart irrigation, and a multitude of additional low-cost devices needed for residential use. Like Nordic, Semtech will offer development kits to help integrate its LoRa devices and the LoRaWAN protocol with Amazon's IoT services.
- Silicon Labs pitches in with its EFR Wireless Gecko Series products to support Sidewalk's sub-gigahertz and Bluetooth LE protocols.
- Texas Instruments gets on the Sidewalk with numerous wireless MCUs, including (among others) its CC1352R (900 MHz and BLE) and CC1352P wireless MCUs; the latter incorporates a +20-dBm power amp for extended-range scenarios. TI also offers a Sidewalk-ready development kit to get applications up and running quickly.

Later this year, many Amazon Echo devices will support Amazon Sidewalk using Bluetooth LE, and those Echo devices will also be able to serve as Sidewalk Bridges. Another pending addition to Sidewalk is Tile devices, those little gizmos that keep you from losing your keys, wallet, or backpack. If you should drop one or the other on the Sidewalk, finding them will be a breeze. You could also hang one off Fido's collar in the event he wanders away from home.

On top of that, Amazon Sidewalk is a community network—those with a Sidewalk Bridge can choose to contribute a small portion of their internet bandwidth to the larger network. Security is provided by three layers of encryption, one-way hashing keys, crypto algorithms, and more.

It's an interesting endeavor, for sure, unless you have reservations about Amazon and its pervasiveness. Maybe you won't mind as much when their drones start delivering your pizzas. mw



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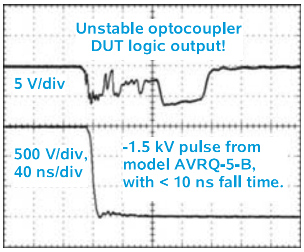

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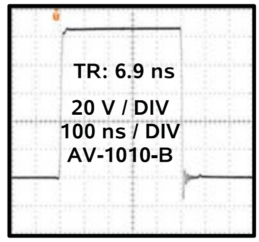

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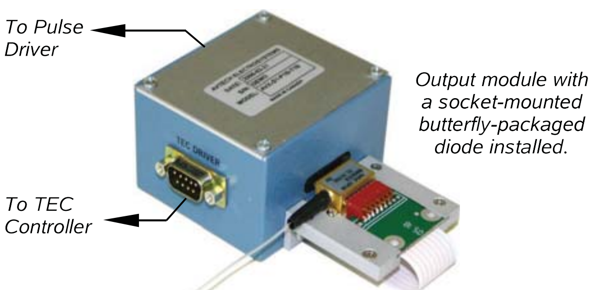

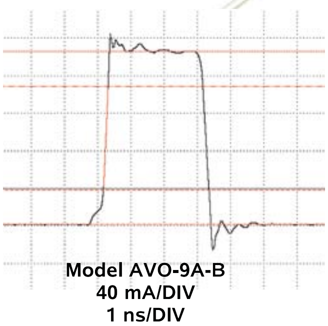

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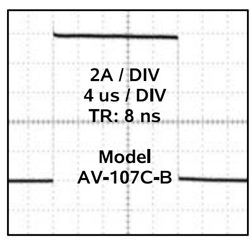

Series	I, V	PW	TR
AV-107	2 - 20 A, 60 V	0.2 - 200 us	10 - 30 ns
AV-106	5 - 100 A, 100 V	0.5 us - 1 ms	50 ns - 1 us
AV-108	12.5 - 200 A, 100V	2 us - 1 ms	5 - 15 us
AV-109	10 - 100 A, 5 V	10 us - 1 s	10 us
AV-156	2 - 30 A, 30 V	1 us -100 ms	0.2 - 50 us

Avtech has a long history of producing one-of-a-kind custom units.

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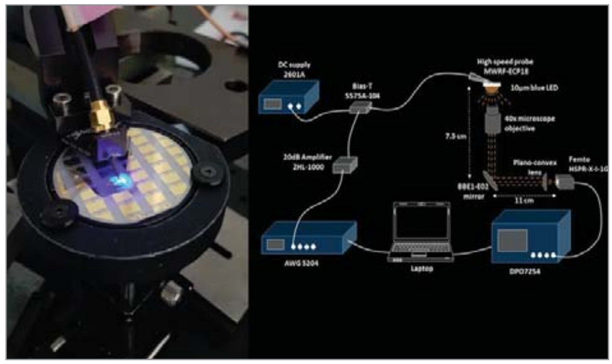
Mitigating Spectrum Coexistence of V2X Systems with High-Performance Filters

Before we can fully realize the safety and efficiency benefits promised by a shift to autonomous vehicles, designers must first overcome spectrum challenges associated with V2X systems.

https://www.mwrf.com/technologies/semiconductors/article/21137924/mitigating-spectrum-coexistence-of-v2x-systems-with-highperformance-filters



Lab-Based "Li-Fi" Link Exceeds 7 Gb/s Using Blue Micro LED

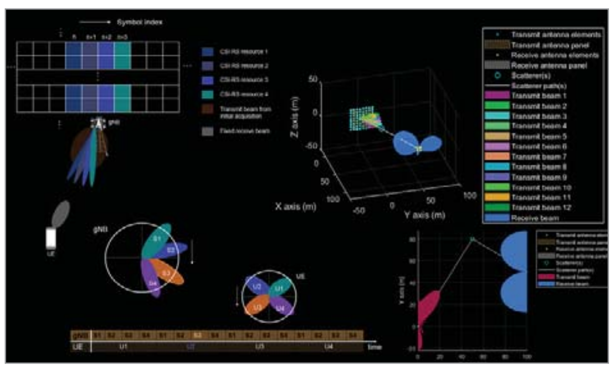
Taking advantage of a blue GaN micro LED, researchers succeeded in operating a free-space optical link at over 7 Gb/s, possibly functioning as a precursor of a super-speed Li-Fi type link.

https://www.mwrf.com/technologies/systems/article/21142476/labbased-lifi-link-exceeds-7-gbs-using-blue-micro-led

Power Sources Aim at Electric Flight

Design efforts at BAE Systems and partner companies are aiming at long-range, long-running helicopters on battery power for commercial and military applications.

https://www.mwrf.com/markets/defense/article/21141104/power-sources-aim-at-electric-flight



5G NR Beam Sweeping and Beam Refinement

This latest edition of "Algorithms to Antenna" shows how you can use beam sweeping at both the base-station (gNB) and user-equipment (UE) ends of a 5G NR downlink system.

https://www.mwrf.com/technologies/systems/article/21142596/algorithms-to-antenna-5g-nr-beam-sweeping-and-beam-refinement

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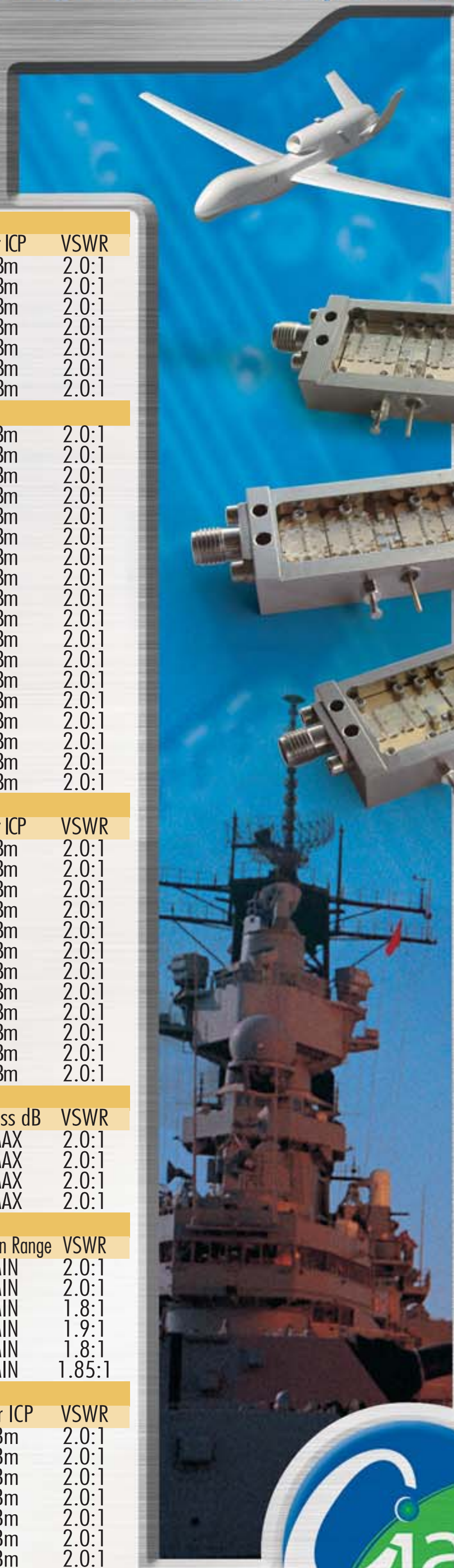

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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News

COMBINING CAPACITORS and Inductors in a Single Component

New hybrid components could shrink the size of electronic filters used in communication devices.

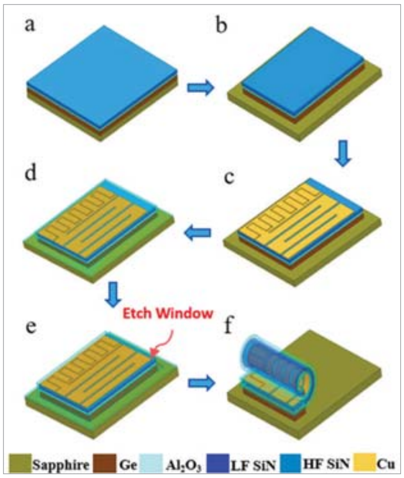
Researchers at the University of Illinois, Urbana-Champaign have devised a method of combining capacitors and inductors in a tiny, 3D rolled membrane. This will save space in the electronic filters found in phones and other wireless devices. They eliminate or enhance specific input signals to get the best output signals. While essential, these filters take up space on the chips that researchers are constantly trying to make smaller.

In the lab, the team used a specialized etching and lithography process to pattern 2D circuits onto thin membranes. In the circuits, they join capacitors and inductors together with ground or signal lines, all in a single plane. The multilayer membrane was then rolled into a thin tube and placed on a chip.

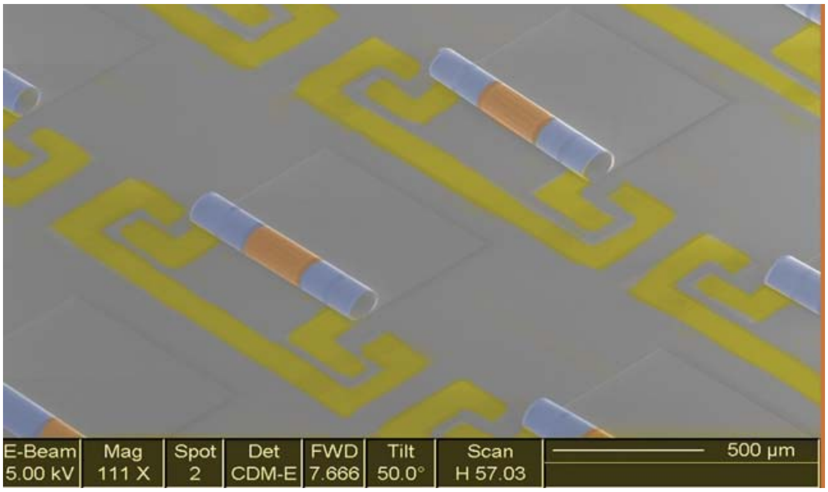
"The patterns, or masks, used to form the circuitry on the 2D membrane layers can be tuned to deliver whatever kind of electrical interactions we need for a particular device," says researcher and grad student Mark Kraman. "Experimenting with different filter designs is relatively simple using this technique because we only need to modify the mask structure to make changes."

The team tested the rolled components performance and found that the filters were suitable for applications in the 1- to 10-GHz frequency range. Although the designs are for use in RF communication devices, the team is confident that other frequencies, including those in the megahertz range, will be possible based on their track record in developing high-power inductors in past projects.

The team is working with several simple filter designs but says filter network combinations can theoretically be made using the same process. The researchers suggest their method of combining inductors and capacitors monolithically could bring passive electronic circuits to a whole new level. ■



Combining capacitors and inductors on a single cylindrical tubular component begins with depositing metals using electron-beam evaporation and lithography to define the metal pattern and etching process. The final etching step triggers the self-rolling process of the stacked membrane. *(Credit: Xiuling Li)*



This electron microscope image shows an array of new chip components that combine the inductors (blue) and capacitors (yellow) needed to make electronic signal filters in phones and other wireless devices. *(Credit: Xiuling Li)*

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IoT STEPS UP to Create Connected Campuses

ZYTER'S SMART UNIVERSITIES, an Internet of Things (IoT) connectivity platform designed specifically for school campuses *(www.zyter.com/IoT)*, hopes to transform student life both on and off campus through smart classroom-based teaching, enhanced communication, and collaboration via secure remote learning, as well as wayfinding, navigation, and other personalized engagement options, all using familiar mobile devices. The platform also provides campus administrators with complete visibility of what is happening across an entire network of connected devices and sensors deployed around campus, supported by advanced analytics.

Zyter's IoT platform enables the launch of new capabilities that enhance daily life on and off campus in three key areas:

SMART UNIVERSITY AND CONNECTED CAMPUS

Smart Universities helps higher-education providers create a connected campus experience with embedded smart technologies and sensors for facilities and utility management, surveillance, and security with video analytics, campus navigation, on-campus transportation, smart parking, and more. As a result, campus administrators can maximize resource utilization, minimize waste, and lower operational and labor costs. Additionally, Zyter SmartSpaces delivers a consistent stream of data from all connected technologies to drive better analytical insights into both student behavior and campus operations.

SEAMLESS STUDENT EXPERIENCE MANAGEMENT

Smart Universities connects students and faculty for a more meaningful and productive campus experience. It enables interactive smart whiteboard-based teaching, personal and real-time engagement with students on mobile devices through smart campus navigation, secure file transfer, and private group/broadcast messaging, as well as classroom chat. Faculty members have access to a dynamic dashboard with student data and behavioral analytics to predict student outcomes, increase student participation in campus activities, and view and respond to any student issues.

DISTANCE LEARNING AND ONLINE COLLABORATION

Online-collaboration capabilities provide students with unlimited access to educational resources in a seamless digital experience, especially valuable during the Coronavirus pandemic. As Smart Universities is one of the most secure remote learning platforms for continuing education, it can be used by higher-education providers to attract a larger pool of remote students and boost enrollment. Zyter Smart classrooms enable collaborative remote learning, using multiple tools like interactive smart whiteboards, smart annotation, analytics, smart videos and more. ■

RF/IF RECORDER SAMPLES to 6 GB/s

FOR HIGH-FREQUENCY, high-speed waveform capture, the Model RTR 2742 rack-mount RF/IF recorder from Pentek can record and play back wideband signals on one or two channels. The latest addition to the company's Talon series of RF/IF recorders *(see figure)* can perform sustained recording of 2.4-GHz signal bandwidths at sampling rates to 6 GB/s using two 12-b, 6.4-GHz analog-to-digital converters (ADCs). It can be configured as a one- or two-channel system and can record real samples or digitally downconverted samples. With a 6.4-GHz, 16-bit digital-to-analog converter (DAC), it can play back analog bandwidths as wide as 1.28 GHz.

Pentek vice-president Rodger Hosking observed: "Many communications and radar applications operate across ultra-wideband frequencies. Now we can satisfy the many customers who need to digitize and record these signals with bandwidths as high as 2.4 GHz." He added, "With the Talon RTR 2742, engineers can capture the whole spectrum in a single wideband channel, eliminating the need to break up the signal into smaller bands, covering adjacent slices of the spectrum."

The RTR 2742 can be equipped with as much as 122 TB of solid-state memory, removable from the front panel. Data are stored in the New Technology File System (NTFS) standard format, allowing users to remove drives from the instrument and read waveform data using standard Windows-based systems, eliminating the need for file-format conversion. The chassis is equipped with front-panel USB ports and rear-panel input/output (I/O) connectors. The digital recorder is based on a Microsoft Windows operating system (OS) and operates under control of Pentek's SystemFlow software with its graphical user interface (GUI), Signal Viewer software, and application programming interface (API). ■

PENTEK, www.pentek.com

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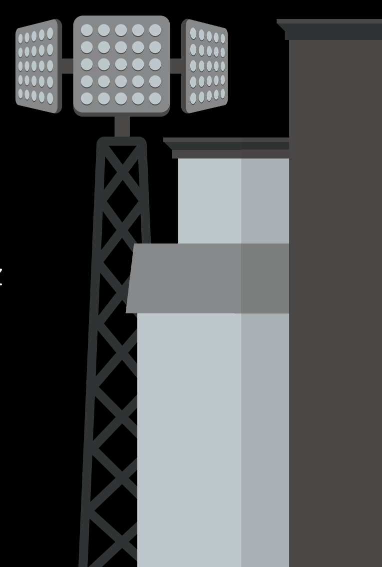

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IN-VEHICLE CONTROLLER Wirelessly Charges Two Mobile Devices at Once

NXP SEMICONDUCTORS NOW OFFERS the first multi-device, in-vehicle wireless charging solution driven by a single controller and available now in production vehicles. In adopting the new 15-W wireless power standard, NXP's MWCT series charge controllers enable faster charging and let automakers deliver a way for driver and passenger to both wirelessly charge mobile devices on a single console.

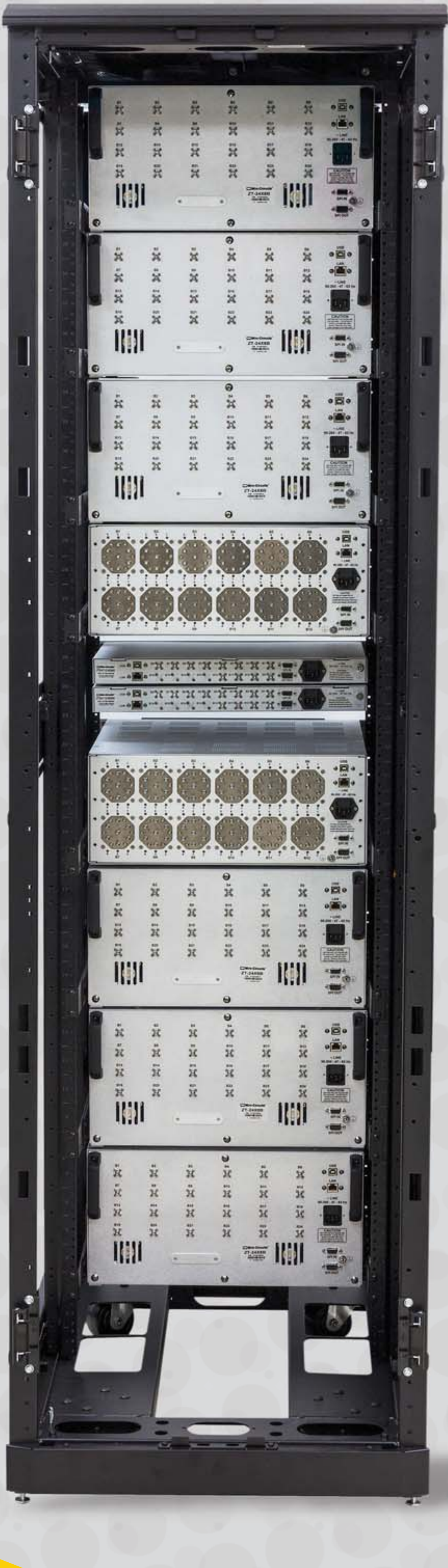
Using a single MWCT device in the vehicle enables carmakers to benefit from reduced cost and physical footprint for device charging. Based on the Qi standard, the controller supports all Qi-enabled phones, including iPhone, Samsung, Huawei, Xiaomi, and others.

Smartphones, ubiquitous as they have become, are increasingly interoperable with vehicles in applications such as smart car access with NFC. Consumers need their phones to be charged on-the-go to access information, make purchases, maintain contact with friends and family, and tap emergency services when required. Wireless charging is an elegant solution that gets rid of bulky chargers and cords and is increasingly in demand.

The new MWCT series is enabled by NXP's hybrid DSC core with dedicated peripherals that allow the two Qi protocols to run in parallel in a single MWCT controller. New patented technologies, such as Clean EMC (CEMC), are said to provide breakthroughs in electromagnetic compatibility performance, which is required for CISPR 25 Class 5 in 15-W systems. As a result, OEMs can reduce the overall system bill of materials.

Additional features of the MWCT controllers include:

- Multi-coil supported per channel for expansion of charging area
- Hardware and software solution with NXP's Qi library powers millions of Qi-certified in-vehicle chargers in the field
- Optional NFC for convenience features such as BLE/Wi-Fi pairing, smart car access with NFC, in-car purchases, and NFC card damage protection
- Future Qi spec is release-ready and includes automotive-grade security to fulfill upcoming requirements
- Patented CEMC signal processing for CISPR 25 Class 5
- Enhanced safety performance via Foreign Object Detection (FOD) methods
- Production-ready hardware design files and available software ■



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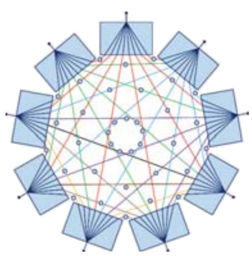

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WI-FI ALLIANCE OKAYS CEVA's Wi-Fi 6 IP Platform

IN ITS RIVIERAWAVES Wi-Fi 6 IP platform, CEVA has what's claimed to be the world's first Wi-Fi IP to achieve Wi-Fi CERTIFIED 6 Status from the Wi-Fi Alliance. CEVA offers a complete suite of Wi-Fi 6 IPs, spanning 1x1 20 MHz for low-power IoT devices through MIMO 80/160-MHz Wi-Fi 6 and 6E for higher-end products including smartphones, smart TVs, access points, and wireless infrastructure. CEVA's Wi-Fi 6 IPs have already been licensed to multiple semiconductor companies and OEMs for upcoming products.

The Wi-Fi CERTIFIED 6 certification is designed to distinguish Wi-Fi 6 products and networks that meet the highest standards for security and interoperability to deliver exceptional end-user experiences and wireless stability. Wi-Fi CERTIFIED 6 products provide significant capacity, performance, and latency improvements to the entire Wi-Fi ecosystem, while ensuring that solutions from multiple vendors interoperate to help enable greater innovation and opportunity.

The RivieraWaves Wi-Fi IP family offers a comprehensive suite of IPs and platforms for embedding Wi-Fi connectivity into SoCs/ASSPs addressing a broad range of applications. The RivieraWaves Wi-Fi 6 IPs are aimed at the vast array of media-sharing consumer devices including smartphones, tablets, cameras, and smart-home products. These are the industry's smallest footprint and lowest power but high-performance Wi-Fi IPs compliant with Wi-Fi 6 1x1 and 2x2.

The IPs of Wi-Fi 6 MAC and Modem are available in both 1x1 SISO and 2x2 MIMO configurations. They are provided with LMAC (aka thinMAC) for use with Linux/Android mac80211 UMAC, LMAC+UMAC (aka FullMAC), and LMAC+UMAC integrated into FreeRTOS (aka FullyHosted) software protocol stacks. They also have an integration-ready processor and OS-agnostic platform, simplifying deployment in SoC/ASSP designs. The Wi-Fi software protocol stacks can be executed on any processor such as Arm, RISC-V, ARC, Andes, and others. The RivieraWaves Wi-Fi 6 platforms can be used in a standalone single chip or integrated into a bigger system on chip, such as an application processor, baseband processor, or multi-standard wireless combos. ■

CEVA, www.ceva-dsp.com

FLEXIBLE DIGITAL-I/O INSTRUMENT Bolsters PXI FPGA Lineup

WITH 56 CHANNELS OF TTL logic-compatible I/O, Marvin Test Solutions' GX3756 Series digital-I/O instrument proves a versatile tool for military, aerospace, and industrial applications. The 56 channels come segmented into 14 four-channel groups in a high-performance 3U PXI hybrid slot-compatible instrument. Each I/O channel can be accessed utilizing read/write register commands and each group of four TTL outputs can be either enabled or tri-stated. The GX3756 comprises the GX3700 FPGA carrier card with Altera's Stratix III FPGA and an I/O daughtercard. The FPGA may be modified by customers to create customer-specific functions.

Four of the 56 TTL outputs can be configured to deliver 30-bit, 1-kHz serial data streams, while connector/cable identification is supported with three connector ID bits, further enhancing the utility of this card. TTL-input overvoltage protection ensures safe, reliable operation, and output state monitoring with the readback function provides the ability to verify programmed operation. A ruggedized, extended-temperature version is available for deployment of test systems in harsh environments.

The GX3756 Series is supplied with GxFPGA, a software package that includes a virtual instrument panel, and a Windows 32/64-bit DLL driver and documentation. Interface files are provided to support access to programming tools and languages such as ATEasy, LabVIEW, C/C++, Microsoft C#, and Visual Basic. NET. A Linux driver is also provided with the GtLinux software package. ■

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JOSEPH SFEIR | Director of Business Development, LitePoint

What's the Difference Between Bluetooth Low Energy, UWB, and NFC for Keyless Entry?

Automotive keyless entry brings convenience, but this feature gives hackers a new way to unlock or steal cars. Learn about the communication protocols involved and how UWB can make this more secure.

With the COVID-19 pandemic shelter in place and significant numbers of employees now working from home, consumers are driving less and, unfortunately, seeing an increase in auto theft. In fact, with cars left unattended for longer periods of time, the Associated Press reported in May 2020 that major cities like New York City and Los Angeles have seen an increase in auto theft.

Even before this "new normal" we're experiencing in the age of COVID-19, the National Insurance Crime Bureau (NICB) reported that 209 vehicles, on average, were stolen *each day* across the U.S. due to drivers forgetting key fobs in their vehicles, making for easy theft.

While leaving key fobs behind is an unfortunate mistake leaving drivers vulnerable to theft, another vulnerability is making car thefts easier—smart keys and smartphone car access.

While keyless entry is a standard on many cars sold today, the feature isn't totally secure. For all of the convenience smart keys and smartphone access brings to drivers, it has given hackers a new way to unlock or steal cars through the wireless protocols that enable the entry. This is because current wireless protocols used for access are susceptible to criminals hijacking a car key's signal.

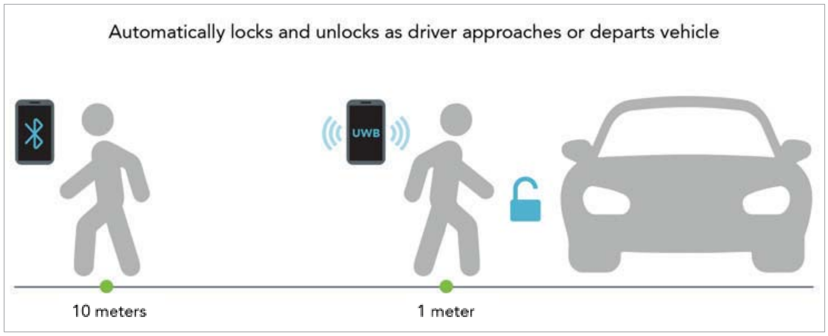
Three communication protocols are involved in enabling a smart key or smartphone for unlocking a vehicle: Bluetooth Low Energy, ultra-wideband (UWB), and near-field communication (NFC), the latter mostly used as a backup. The three communication protocols, however, aren't equal in terms of access security.

BLUETOOTH LOW ENERGY

For quite some time, Bluetooth Low Eenergy (BLE) has been used in vehicles to unlock/lock the car and connect multimedia applications—to pair a smartphone with the multimedia console for voice calls or music streaming applications.

BLE is one of the communication technologies used for smart key or smartphone wireless access when approaching a car. In newer car keys, BLE communication is mainly used to track the approach of a driver beyond the 10-meter distance, while also preparing for UWB authentication. By using data packets, BLE relies on the measurement of signal strength to evaluate the distance of a driver.

Unfortunately, despite a certain degree of encryption, BLE can be subjected to jamming and relay or man-in-the-middle attacks. During a relay attack, the communication from the valid key is spoofed by a hacker by amplifying its signal strength and tricking the receiver into believing that the key is nearby. If a hacker can sniff and replay the data exchange between key and car, it's possible to unlock the car and steal it.



1. Shown is the Bluetooth Low Energy and UWB distance for automotive access.

UWB

Ultra-wideband, based on IEEE802.15.4z, is a newer technology standard that can be employed in wireless entry systems to prevent distance manipulation attacks—short UWB pulses are used for precise and secure time-of-flight (ToF) and angle-of-arrival (AoA) measurements. ToF measures the propagation time that it takes for the RF signal to travel between the transmitter and receiver. AoA measures the angle of an incoming signal using multiple antennas. Positions can be determined by having multiple angles, multiple distances, or a combination of the two.

With UWB, once the two devices (in this case, the smart key/smartphone and car) is within proximity, they begin ranging and calculating the distance with a centimeter level of precision between them. The smart key/smartphone can lock or unlock the vehicle when it's within, for example, two meters of the vehicle, depending on the direction of movement (moving away or towards).

Unlike BLE, UWB is based on time, not signal strength. Therefore, a relay attack will not work on UWB, as the attack will add latency to the transmission and indicate that the key is actually far away from the receiver. In addition, adding a Scrambled Time Sequence (STS) into the UWB frame—an "encrypted" measure of a timestamp—prevents preamble insertion attacks and allows for even more accurate distance measurements. *Figure 1* shows BLE and UWB distance for automotive access.

The new technical features enabled by UWB combined with a smartphone can enable not only safer access, but also new services such as locating your vehicle in a parking garage.

REDUNDANCY WITH NFC

NFC provides the same locking and unlocking capability as UWB or BLE, but NFC is mainly used as a redundant system in the event the smart key's or smartphone's battery runs out. Redundancy in automotive applications is very important because a user doesn't want to be in a position of not being able to unlock the car.

When an NFC passive device is brought within the near field of an active device (the car), the passive device "wakes" and communicates with the active device to perform an action, like unlocking the door.

While NFC is a much simpler communication protocol and therefore doesn't have the same security benefits as UWB, it's an excellent backup system for UWB because it's very low power and requires much less battery from the device being used. In some cases, the smart key or smartphone may have a capability built in to recognize the level of power supply that's available at a specific moment and select which communication protocol should be used to unlock the vehicle. It is, however, a less convenient solution than UWB because the car key needs to be held on an active part of the car.

	UWB	Bluetooth LE	NFC
Accuracy	up to +/- 10 cm	1-5 meters	Centimeters
Reliability	Resilient to multipath and interference	Sensitive to multipath and interference	no multipath
Range	70-250m	25-100m	<1m
Data Rate	up to 27 Mbps	Up to 2 Mbps	Up to 424 Kbps
Security	Difficult to jam as UWB signal are made by fast impulse (2ns), supports scrambled timestamp sequence (STS)	Sensitive to Relay attack and jamming	Sensitive to Relay attack
Latency	Typ<1ms	Typ>3s	Typ>1s
Chip cost	~ >$5	~ $2	~ $0.25

2. The chart compares the important technical aspects of each communication protocol.

CONCLUSION

All three technologies may be available in different smart keys and smartphones for enabling keyless vehicle entry. The comparison chart in *Figure 2* summarizes the key technical aspects of each communication protocol.

While a UWB chip is more expensive than BLE, the wireless protocol provides significantly greater security in ensuring that only the driver obtains automotive access. Successful deployments of UWB-enabled smart keys or smartphones will depend on the accuracy of their fine ranging capabilities, making test compliance verification and performance validation imperative to successful implementation.

AMANDA WILSON | Contributor

Rent, Lease, or Buy Electronic Test Equipment? HERE'S HOW TO DECIDE

Evolving technology, certifications, and time are just some of the points to consider before renting, leasing, or buying that next piece of equipment.

> "Whether you are a startup, mid-size business, or a large company, a smart approach to acquiring expensive electronic test equipment is the key."

For every technology-driven business, it's a major concern to strike a tradeoff between high cost, constant maintenance, and calibration of new equipment vs. the need to conserve cash by renting or leasing.

Should you rent, lease, or buy?

A single answer will certainly not fit every company's needs. This article will give you clear, actionable points to decide which approach works best for you.

WHEN TO RENT, LEASE, OR BUY TEST EQUIPMENT

Before deciding to rent, lease, or buy electronic test equipment, study the pros and cons via physical, economic, system, technology, and lifecycle analysis. These are explained below:

Evolving technology

Speed, performance, and technology of digital processors are changing at blazing speeds. New frequencies and improved analog performances can lead R&D teams to evolve their knowledge about test equipment constantly. If you're a product-based company, it depends on the time it takes to develop, test, and launch your product.

If it takes less than six months, it makes more sense to rent the electronic test equipment at a much lower monthly cost. On the other hand, if you're a service-based company that regularly tests and repairs electronic products, you may find it logical to purchase.

Certifications and compliances

Electronic test equipment itself needs to be regularly tested and calibrated in compliance with industry-wide ISO regulations. Without regular testing and calibration, you may get wrong results that defeat the whole purpose of using them.

If you own multiple test equipment across different departments, you may need a dedicated small team to track and manage audits, calibrations, and compliances. This is an additional operational cost over and above the capital cost of owning the equipment.

Small to mid-size companies may see sense in renting or leasing test equipment, where the responsibility of managing compliances lies with the supplier.

Long-term rental

If you need the equipment for more than six months, it may make more sense to calculate the cost of monthly rent vs. purchase. You can also choose to lease the equipment for a limited duration, and subsequently buying it if it makes business sense. You don't want to pay a rental amount that's eventually more than the actual cost of the instrument.

Cash flow in the company's books

Companies manage their expenses based on the cash flow in their books. If you have high sales and profits, you may have sufficient cash flow to lease or outright buy the equipment.

However, for startups with limited cash flow, it makes sense to pay a small rental amount every month that complements the available sales and profits. But then, once again, you may have to factor in the additional cost of certifications and regular calibration.

Tax liability

Buying expensive electronic test equipment costs tens of thousands of dollars. Large companies sometimes choose to offset their annual tax liability by buying the expensive test equipment outright and showing it as an expense in the books. This decision often lies with the senior management, accounts department, and tax advisors of the company.

You mustn't forget the cost of maintenance and possible obsolescence and decide accordingly. Check with your supplier if they provide a buy-back option, which may recover some of the money you invested.

> "According to a study by Frost & Sullivan, test equipment is effectively used for only 15-20% of its entire lifetime, leaving an expensive graveyard of obsolete instruments."

Terms & conditions of the agreement

It's important to read all of the terms and conditions, including the legal fine print in the agreement that you sign with the supplier. You don't want to get stuck with long-term inflexible contracts that end up costing you more than the cost of purchasing the equipment.

If you're a large company that needs multiple test equipment for a longer time, you can also ask for an attractive payment and post-sale service terms.

RENTING, LEASING, AND BUYING OPTIONS

Renting Options (Short-term)

It's suitable for the following scenarios:

- Temporary planned or unplanned projects.
- Peak load capacity requirements.
- Existing test equipment is out for maintenance or training programs.

With renting, you have no fixed time commitment and have the freedom to go for flexible short-term contracts. You needn't worry about obsolescence, maintenance and repairs, compliance, and regular calibration of the equipment. The supplier takes care of it and includes its cost in the monthly rent. You can also rent and test new technology before buying.

Leasing Options (Long-term)

Go for a lease if you can already foresee the time limit that you need to own the equipment. You can pay the fee as a one-time amount or a monthly installment, but the duration of the lease is pre-decided. Choose from the following options:

- *Finance lease:* Many customers who lease the equipment often end up buying it from the supplier after the lease period expires. In a finance lease, the contract is drafted such that the ownership of the equipment lies with the lessee at the end of the term.
- *Operating lease:* If you don't want to own the equipment at the end of the term, you can opt for an operating lease where the ownership will

be retained with the supplier at the end of the term.

- *Operating lease with services/Service lease:* This is the most convenient, but at a slightly higher cost. In an operating lease with services, the supplier takes ownership of maintenance, repair, compliance, and calibration-related jobs for the duration of the lease.

Purchase Options

This is the preferred option for large companies who need multiple equipment and have to use them frequently. Such companies often work on large projects and may want to offset tax liability with fixed asset purchases.

- *New equipment:* As the name suggests, these are brand new products customized and calibrated to your project needs.
- *Pre-owned/refurbished equipment*: These are slightly cheaper pre-owned and used testing equipment that was bought back by the supplier or returned after the lease period was over. Such equipment goes through rigorous functional checks, calibration, compliance updates, and cleaning to make sure that they give optimal performance.

Regardless of new or pre-owned equipment, you get attractive financing options, discounted rates, limited or lifetime warranties, and full-service support.

CHOOSING YOUR ELECTRONIC TEST EQUIPMENT SUPPLIER

No matter what your decision—whether renting, leasing, or buying—it all comes down to working with a high-quality equipment supplier that provides you flexibility in the terms and conditions, attractive pricing and great post-sales service:

- Begin by looking at the range of products offered by the supplier. The higher the range, the more options you will have to source your entire requirement from a single supplier.
- The supplier's technical team should have enough experience to advise you on the right product in your budget.
- Check the supplier's market reputation and its client base.
- The supplier should be able to provide you all of the options, including renting, leasing, and buying, as well as calibration services.
- The equipment supplier should be able to provide both new and used/refurbished products.

Electronic test equipment continues to evolve, and that makes buy, lease, or rent decisions more complex. But based on your company's size, budget, and other requirements, the above actionable points should make your job easier. mw

JONATHAN KAYE | Senior Director of Product Management, Laird Connectivity

11 MYTHS About Cellular IoT Design

Laird Connectivity's Jonathan Kaye discusses the most common misconceptions about cellular IoT design—a growing area of IoT thanks to two new versions of the cellular standard that enable battery life of up to 10 years for wireless devices.

Internet of Things (IoT) implementations typically utilize low-power wireless technologies like Bluetooth, Wi-Fi, and LoRa for connectivity, enabling wireless devices like sensors to remain in the field for extended periods of time on a single battery charge. The low operational costs of those wireless technologies have also made them ideal for IoT, where the sheer number of devices involved in deployments make data-transfer costs important to manage.

Cellular technology has largely been the domain of smartphones and tablets, with limited usage in IoT implementations because of their battery usage and the higher operational costs of data transfer via cellular networks. That dynamic has changed with the availability of two ultra-low-power versions of cellular technology designed specifically for IoT: LTE-M and NB-IoT *(Fig. 1)*.

1. LTE-M and NB-IoT are ultra-low-power versions of cellular technology designed specifically for IoT.

In this article, we'll dispel 11 myths about cellular IoT and explain how the new protocols make cellular technology an attractive option for engineers designing IoT devices and network deployments.

1. The ubiquity of cellular infrastructure would be great as a foundation for connecting IoT devices, but cellular technology would drain a sensor's battery in the blink of an eye.

That was true in the past, but no longer now thanks to the two new versions of the LTE cellular protocol, which were designed specifically for IoT deployments. Yes, the concern about battery drain is very valid when you look at the version of cellular technology that's used in iPhones, Galaxy mobile phones, tablets, and other consumer devices. Those devices require an "always-on" approach that aligns with how they're used, with functions and apps that regularly check the network for messages, calls, and other functions.

The cellular standard for consumer devices is also designed to handle high-throughput applications like video streaming. It's a constant drain on batteries, which is why our kids are always hyper-aware of the battery level on their devices and looking for a place to plug in. Such a protocol would drain an IoT device's battery in a hurry, but temperature sensors don't need to watch YouTube videos.

The new LTE-M and NB-IoT protocols use sleep cycles and other clever hardware and software engineering approaches to sip energy rather than guzzle it. Note that LTE-M/NB-IoT hardware can be scaled down by this bandwidth limitation, allowing the device to be less processor-intensive and therefore less of a power drain. These qualities combine to allow a device's battery to last for 10 years or more in the field.

2. Cellular technology isn't built for low-bandwidth devices with infrequent data transfers.

That may be true with the version of cellular for your iPhone or Galaxy, but it's not true for LTE-M and NB-IoT. These two new cellular protocols designed for low-bandwidth IoT applications use wireless devices that only need to transfer data infrequently. After those occasional data transfers, the sensor or other device can quickly go back to sleep, minimizing the drain on the battery *(Fig. 2)*.

3. But my deployments are really big. There's no way cellular IoT could be cost-effective.

LTE-M and NB-IoT were designed to have operational costs at scale that make them competitive with other protocols used for IoT deployments. The operational costs and total cost of ownership of cellular IoT will be eye-opening to engineering teams.

It's also important to keep in mind that LTE-M and NB-IoT remove the network infrastructure from the customer's and OEM's cost structure. By using public cellular network infrastructure, the organization doesn't need to deploy the network, own it, and maintain it. Those costs are borne by the wireless carrier,

The cellular standard for consumer devices is also designed to handle high-throughput applications like video streaming. It's a constant drain on batteries, which is why our kids are always hyper-aware of the battery level on their devices and looking for a place to plug in.

2. Ultra-low-power cellular protocols designed for low-bandwidth IoT applications use wireless devices that only need to infrequently transfer data. After those occasional data transfers, the sensor or other device can quickly go back to sleep, minimizing the drain on the battery.

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3. Many cellular IoT deployments will involve implementations of multiple wireless technologies. This makes it critical for cellular IoT to work well alongside other wireless protocols, such as Bluetooth, which can handle short distance device-to-device communication while LTE-M/ NB-IoT handles the backhaul communication to the network.

which eliminates a source of operational costs for IoT deployments.

4. Designing with cellular technology is complex and frustrating.

Cellular design with the protocol intended for smartphones and tablets is indeed complex. That's a discipline unto itself in the wireless engineering industry, but the two IoT-specific versions of the cellular protocol are far simpler to work with than traditional cellular. It was a guiding principle of the working group that created LTE-M and NB-IoT, specifically because of the perception that cellular technology was difficult to work with.

Yes, these cellular IoT protocols are still more complex to certify than Bluetooth, for example. However, embedded solutions can sidestep that complexity, reducing the risks that are part of testing and certification for wireless projects.

5. The carriers don't care about IoT. They make their money elsewhere and IoT isn't a priority.

There's a misconception that carriers would be hostile or, at best, indifferent to any use of their networks not related to their primary services to consumers and business clients. The opposite is true: Carriers see the growth of IoT as a way to make their networks more vital and to be more robustly utilized by balancing different kinds of data traffic across the same infrastructure. For that reason, telecom carriers played a pivotal role in making LTE-M and NB-IoT possible.

The working group that created the two protocols wanted to ensure IoT deployments using cellular infrastructure as a foundation would be well-supported by carriers. These protocols represent a win-win for the carriers and organizations doing cellular IoT deployments.

6. Approving the technology is one thing, but carriers will never care about IoT enough for me to have important IoT deployments rely on them.

The reality is that carriers are competing hard for IoT customers. They wouldn't be devoting resources to this if they didn't see it as vital to the value of their networks, as discussed in Myth #5. By making their networks a backbone for IoT, carriers are aligning themselves with one of the fastest-growing areas of the wireless industry.

Carriers aren't hostile or indifferent to IoT. They see it as a key to their future because there's an upper limit on how many cellular subscriptions can be derived from consumer devices like smartphones and tablets. By making their networks a viable backbone for IoT implementations, carriers can drive growth by supporting billions of additional devices.

4. Industrial monitoring represents one of the many applications for cellular IoT.

7. Ten years of battery life is pure marketing fluff. There's no way that's possible in the real world.

I'm as skeptical as they come when it comes to spec sheets about wireless technology, but this isn't a marketing claim. It's math. Yes, the exact math depends on the size of your battery and other aspects of your design, but the battery life of LTE-M and NB-IoT devices is remarkable.

LTE-M and NB-IoT are designed with sleep/wake cycles that enable engineers to have devices successfully serve their purpose while sipping energy in remarkably small amounts. The key capabilities involved are called Power Saving Mode (PSM) and Extended Discontinuous Reception (eDRX), which work in concert with each other to extend battery life.

PSM allows devices to be programmed to go into a deep-sleep mode while still being reachable. eDRX optimizes the length of time between paging cycles, which can be extended in 10.24-second increments for long periods of inactivity in between activating a paging window. Together, these two technologies make 10-year battery life a potential reality (again, depending on your device design and battery size) in real-world settings rather than just a marketing claim.

8. I can't use cellular IoT because I don't know which protocol I will end up using for each IoT device that's provisioned.

Engineering teams don't face an either/or decision when it

Engineering teams don't face an either/or decision when it comes to LTE-M and NB-IoT. Unlike some other wireless protocols that force you to make hard choices early in the design process, cellular IoT allows you to embed both technologies in a device.

comes to LTE-M and NB-IoT. Unlike some other wireless protocols that force you to make hard choices early in the design process, cellular IoT allows you to embed both technologies in a device. Therefore, your team has the option of using one or the other as best suits the implementation, as well as the flexibility on how that device will be used later on. The provisioner will be able to optimize the device's and IoT network's performance later by leveraging whichever makes the most sense on a device-by-device basis.

9. Cellular certification is arduous, and I can't afford to have it lengthen my time to market for this IoT project.

Yes, certification of cellular has more layers when compared to a technology like Bluetooth, but that process can be de-risked and accelerated by using pre-certified modems based on LTE-M and NB-IoT. The layers of certification for cellular include radio regulatory (FCC/IC, and so on), network (PTCRB/GCF), and carrier (AT&T certifications). Working with pre-certified wireless components and an experienced wireless-design partner can help navigate those steps to minimize setbacks and speed time to market.

10. I also want to use other wireless technologies, but cellular has never played nicely in the sandbox.

I believe a large percentage of cellular IoT deployments will involve implementations of multiple wireless technologies, which makes it critical for cellular IoT to work well alongside other wireless protocols *(Fig. 3)*. Bluetooth is a particularly attractive complement to LTE-M and NB-IoT, with Bluetooth doing the short distance device-to-device communication and LTE-M/NB-IoT doing the backhaul communication to the network.

Companies combining cellular IoT with other protocols like Bluetooth need to carefully navigate how to co-locate multiple radios to optimize performance and successfully pass certifications. Pre-certified solutions that take care of the cellular-and-Bluetooth integration make the process even simpler and faster for engineers.

11. Cellular IoT is interesting, but it's not relevant for very many real-world projects.

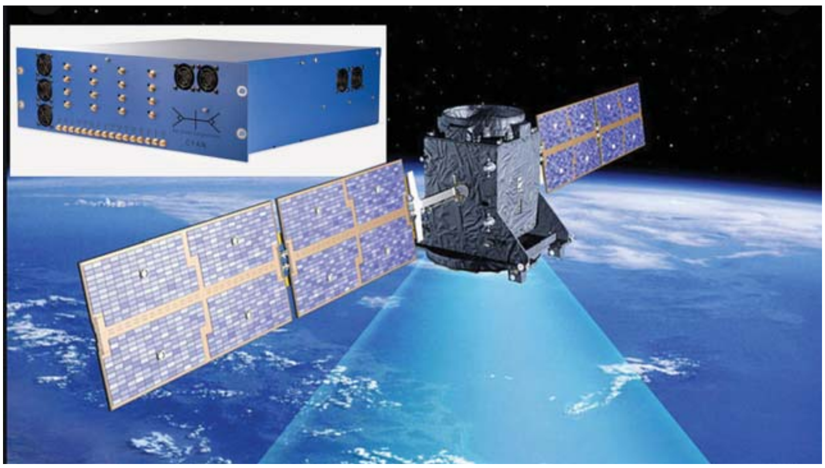
Now that engineering teams are realizing that cellular technology is practical and cost-effective for IoT projects, the number of use cases they're looking at spans across a long list of industries and business needs. A white paper from Laird (see online version of article for link) does a deep dive into three cases that utilize cellular IoT and Bluetooth technologies for actual applications involving cold-chain monitoring, industrial equipment monitoring *(Fig. 4)*, and electric charging stations. These three cases just scratch the surface of how cellular IoT will be used. mw

JOHN POLAK | RF Hardware Designer for SDR, Per Vices Corp.
ETIIDO MAURICE UKO | Mechanical Engineer

The Value of SDR Integration Across Industries

Software-defined radio is a flexible radio communication and signal-processing system that performs at very high levels for applications across radar, MRI, GNSS, low-latency links, and test and measurement.

Software-defined radio (SDR) is a radio communication and signal-processing system in which certain functions typically carried out by hardware components are instead performed by software. Replacing specific hardware with software creates a flexible, high-performance system that's unattainable by hardware-only systems.



An SDR typically consists of an SDR platform and a computer or embedded system containing appropriate software. SDRs come in various flavors with a wide range of capabilities. While functionality is controlled by software, the level of capability depends on the given SDR platform.

The essential functions of SDRs are receiving and transmitting radio signals and, in some systems, digital signal processing. SDRs capable of transmitting or receiving only are called transmitters or receivers, respectively, while SDRs that perform both functions are called transceivers.

SDR ARCHITECTURE

SDR architecture comprises the following:

The *radio front end* (RFE) contains most of the components that have been replaced with software. The configurable RFE of SDRs is what gives them their flexibility and versatility. Components in the RFE include filters, mixers, amplifiers, variable-frequency oscillators/tuners, and I and Q converters. In radio-frequency (RF) reception, these components are responsible for setting the SDR to the right band, frequency, and bandwidth, as well as for preparing the received signals for analog-to-digital conversion. In RF transmission, the RFE prepares signals converted from digital to analog for transmission at the right frequency.

The *analog-to-digital converters* (ADCs) in a receive-board radio chain convert the I and Q signals received from the RFE to digital signals that can be processed by the digital signal processor (DSP). *Digital-to-analog converters* (DACs) are used in transmit-board radio chains to convert digital signals from the DSP to analog signals.

The *DSP* processes received signals into data before sending them to the host computer. It also processes data from the host computer into signals that can be transmitted. Data is transferred between the DSP and the host system via digital backhaul. Depending on the SDR platform, the DSP may be implemented using field-programmable gate arrays (FPGAs), a hard processor system (HPS), application-specific ICs (ASICs), or a combination of more than one of these.

In some SDR systems that don't have DSPs, digital signal processing is carried out by the host computer's processor.

In receive-board radio chains, the *host system* is at the end of the chain. It presents the data contained in the received signals. This could be via data processing, imaging, payload decryption, tracking, and many others. The host system in transmission chains prepares the data to be transmitted before sending it to the DSP. See *Figures 1 and 2* for block diagrams illustrating the roles of SDR architecture.

APPLICATIONS OF SDR

Because of their high functionality and capabilities, which include broad frequency range, high bandwidth, and advanced signal processing, SDRs are found in applications across numerous fields and industries. These include medical, aerospace, broadcasting, defense, civil communication, and virtually all fields that employ radio technology. Five specific applications for which SDR is immensely beneficial and indispensable are radar, MRI, GNSS, test and measurement, and low-latency links.

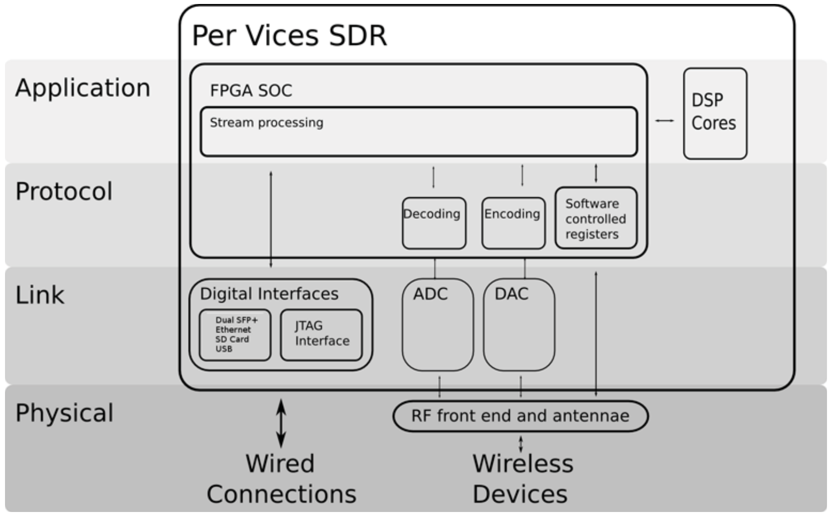
SDRs are used in radar applications as transmitters, receivers for returning signals, and DSPs. They can also be configured to work as transponders that only transmit signals when triggered by incoming signals. SDRs are used in primary and secondary radars, general pulse radars, maximum range resolution radars, and the like.

Magnetic resonance imaging (MRI) employs SDR to generate and transmit the radio waves needed to excite low-energy water molecules in the human body. SDR is also responsible for receiving and processing the return waves before forwarding the data to a computer for imaging.

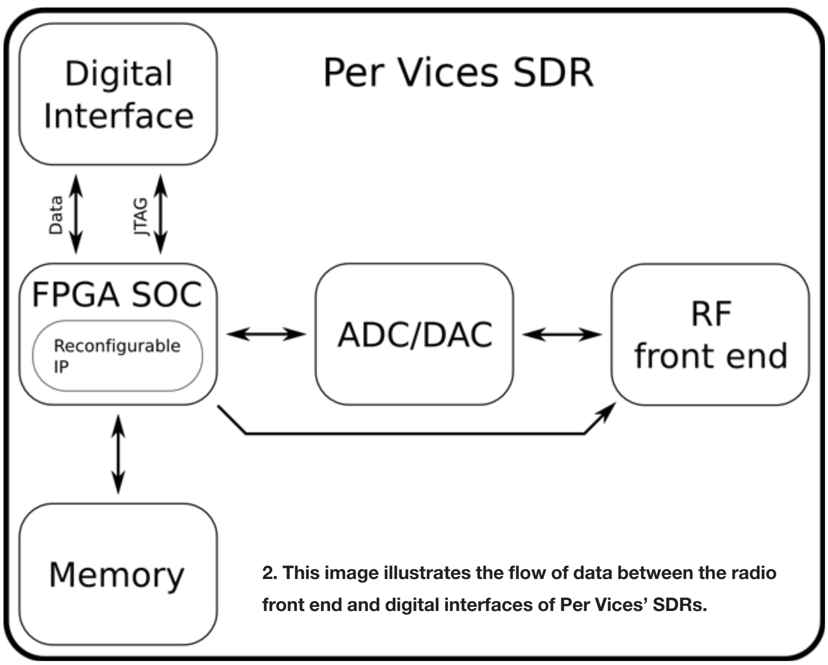
In Global Navigation Satellite System (GNSS) applications, SDR receivers on a device receive signals from satellites in a satellite navigation system's constellation. The DSP processes the received signals to calculate the device's position. SDRs are employed in GNSS for locating and tracking missiles, drones, aircraft, vehicles, and more.

After setting up a radio system, it's necessary to thoroughly check that all operations are going smoothly. The same goes for manufactured equipment. SDRs are used to test various radio equipment and systems, reducing development time and time to market.

SDRs are use used to set up low-latency links for wireless point-to-point communication systems. The use of SDRs helps reduce receive and transmit latency as well as round-trip latency.



1. The diagram provides an overview of Per Vices' SDRs and where the application layer and protocol layers are implemented, along with the links and physical connections.



2. This image illustrates the flow of data between the radio front end and digital interfaces of Per Vices' SDRs.

The features of SDR have numerous advantages and benefits in the aforementioned applications. Three key beneficial features of this technology are the architecture, configuration, and bandwidth. These features of SDR and their advantages in the applications mentioned are explained in the next section.

ARCHITECTURE BENEFITS OF SDR

Advanced radio applications usually require various large pieces of equipment working simultaneously to perform the numerous operations involved in receiving, transmitting, and processing radio signals. Such systems are complicated, chunky, and costly to set up, run, and maintain, and may be susceptible to inefficiencies.

SDRs provide fully integrated and highly compact systems with both RF and digital processing resources. These systems are more capable, functional, cost-effective, efficient, and easy to

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manage. Among the advantages of SDR architecture in popular applications are:

- For radar applications, a fully integrated SDR system can be used as a radio receiver, radio transmitter, digital signal processor, or a combination of all three. The DSP also provides waveform storage in addition to digital signal processing.
- In MRI, SDR architecture can serve as both a pulse generator (exciter/radio transmitter) and a digital receiver (RF acquisition/radio receiver). It also allows for easy integration into existing systems, as well as external and internal triggering.
- In GNSS applications, SDR provides radio receiver and transmitter resources. Various satellite navigation systems are in use today, including GPS, GLONASS, Galileo, and BeiDou. These systems employ different constellations to function. The FPGA resources of SDRs are flexible enough to implement different constellations. This means that a single device affords access to various satellite navigation systems.
- SDR architecture is also very useful for test and measurement applications—it can be used to test both radio and digital devices. The same system can serve as receiver, transmitter, oscilloscope, signal generator, network analyzer, power meter, spectrum analyzer, and more for testing telecommunication, aerospace, military, and other radio equipment systems.
- Processes in a radio chain such as mixing, filtering, signal conversion, and signal processing all contribute to latency. Having all RF and digital processing components in one system helps reduce overall system latency. An integrated system also allows for modem operation on FPGAs and offers a direct network connection through the digital interface. These result in faster data transfer and processing.

CONFIGURATION BENEFITS OF SDR

Radio technology has numerous applications that require different configurations. Each of the applications being discussed are broad and may require a wide range of settings. In traditional systems, changing settings such as frequency band, bandwidth, number of channels, and receive and transmit chains may require new systems or equipment. With SDRs, however, only a simple change via software is required to create different systems.

If the need arises, an SDR's configurable RFE makes it possible to use a single piece of flexible hardware for an extensive range of applications by simply updating the software later on. SDRs have digitally controlled attenuation, adjustable bandwidth, and flexible operating frequencies, among other parameters. There are multiple configuration benefits of SDR particular to radar, MRI, test and measurement, GNSS, and low-latency links applications. For instance:

Different radar applications utilize various bands in the radio spectrum. Airport surveillance radars, for example, operate at frequencies in the S-band while marine radars operate at frequencies in the X-band. Having a configurable RFE makes it possible for the same SDR platform to be used in different radar applications as bands can easily be adjusted.

The RF range used in MRI depends on the magnetic-field strength and is usually between 1 and 300 MHz. The configuration features of SDR allow for flexible operating frequencies in MRI applications.

Furthermore, satellite navigation systems make use of various bands. Some systems utilize different frequencies within the same band. GPS, for example, operates at frequencies in the L1, L2, and L5 bands. SDRs can be configured to operate at various bands; thus, one platform can be used for various SatNav systems.

New radio equipment is continually being manufactured. It's crucial to thoroughly test such equipment for various applications. In traditional systems, a new radio system or some new hardware would need to be designed/acquired for every new device/protocol being tested. A simple change of software is all that's needed when using SDR. Configurable SDRs can be used to test multiple devices operating at different frequencies, such as HF, UHF, VFH, and so on.

In low-latency links, configurable RFEs provide considerable control in reliability vs. latency tradeoffs. They also make it possible to transmit and receive at optimal frequencies by tuning to the least-congested band. Furthermore, filtering can be implemented to improve signal-to-noise ratio.

BANDWIDTH BENEFITS OF SDRs

SDRs have several bandwidth benefits. They can transmit and receive signals at much higher bandwidths than traditional radio systems. This allows them to handle different sizes of data in different bands. SDRs also feature adjustable RF bandwidth, making the amount of transmittable and receivable data variable.

Such precise adjustment is key in several applications. Because they're able to operate across multiple bands simultaneously, SDRs can be used to tune to all required bands in an RF application simultaneously, eliminating the need for separate radio chains. Adjustable bandwidths also make it possible to test equipment operating at different bandwidths and over various bands without limitations.

CONCLUSION

SDR offers numerous important benefits in various applications, and it's still undergoing development for even more applications. The technology greatly improves the capacity, speed, and cost-effectiveness of any application to which it's applied.

Multiple manufacturers make many types and models of SDR. These can vary widely in capability, functionality, and application. As a result, it's crucial to select the SDR platform that best fits all your current and anticipated future needs. mw

CHARLES DACHS | Vice President of Secure Embedded Transactions, NXP Semiconductors

ULTRA SMART, ULTRA SAFE:
How UWB Can Benefit the Smart Retail Ecosystem

The retail experience is gearing up to get a whole lot smarter. Smart Retail initiatives centering on ultra-wideband technology could enhance the shopper experience, all while bringing new opportunities to the retail ecosystem.

The coronavirus pandemic of 2020 has changed the world in many ways, and one of the most remarkable transformations has been that of consumer retail. Market research from Kantar[1] indicates that the number of consumers who did more than half of their shopping online in Europe's three biggest e-commerce markets rose as much as 80% during the pandemic, and six in 10 respondents say they intend to continue shopping online at the same levels for the foreseeable future, even after the pandemic has passed.

The availability of e-commerce and the fear of viral transmission pose significant threats for the existence of brick-and-mortar outlets. Stores need to adapt their offerings to make consumers feel safer in the "new normal" while still providing that all-important element of retail therapy at a physical store. In the post-COVID era, shopping needs to be quicker, easier, and less congested than ever before.

On top of the current retail trends for personalization and "retailtainment" that create tailored recommendations and unique experiences, retailers are now rushing to create a shopping experience that reduces or eliminates queuing, personal contact, and commonly touched surfaces.

In Finland, Neste has used RFID solutions to fully automate its Easy Deli self-service stores. Items picked from the shelf are deposited in the self-service checkout, where the RFID tags are read and rung up on the register. Once the items have been paid for, the tags are deactivated and the customer leaves the store.

Amazon's "just walk out" technology is also rolling out globally. Using advanced machine learning, computer vision, and artificial intelligence, Amazon has done away with lines, checkouts, and registers completely. Shoppers activate their Amazon Go app, enter the store, and start shopping. Anything the customer picks up is added to the virtual cart automatically and, when they leave, the items are charged to their Amazon account.

Even now that most shopping occurs online, click-and-collect services remain popular with consumers. With 275 million customers a week, U.S. retail giant Walmart pulls off omni-channel commerce on a staggering scale. By using geolocation via the Walmart mobile app, retail stores are alerted when a customer is about to arrive to pick up their orders. The collection process to get the order ready is triggered in advance and the handoff is much quicker.

INTRODUCING UWB TECHNOLOGY

At this crucial moment in retail history, how does ultra-wideband (UWB) technology fit into the digital wireless technology puzzle, and what can it offer?

UWB, standardized by IEEE 802.15.4z, is an extremely precise ranging and sensing wireless protocol. The ranging is done by performing time-of-flight (ToF) and angle-of-arrival (AoA) measurements between two UWB-enabled devices.

On the radio spectrum, UWB operates far away from the busy industrial, scientific, and medical (ISM) band clustered at around 2.4 GHz. Because it operates between 6.5 and 9 GHz, the technology can safely coexist with other communication frequencies. And, as UWB can send pulses of 2 ns long across a very wide radio spectrum, the technology is able to differentiate multipath signals caused by reflections from nearby objects.

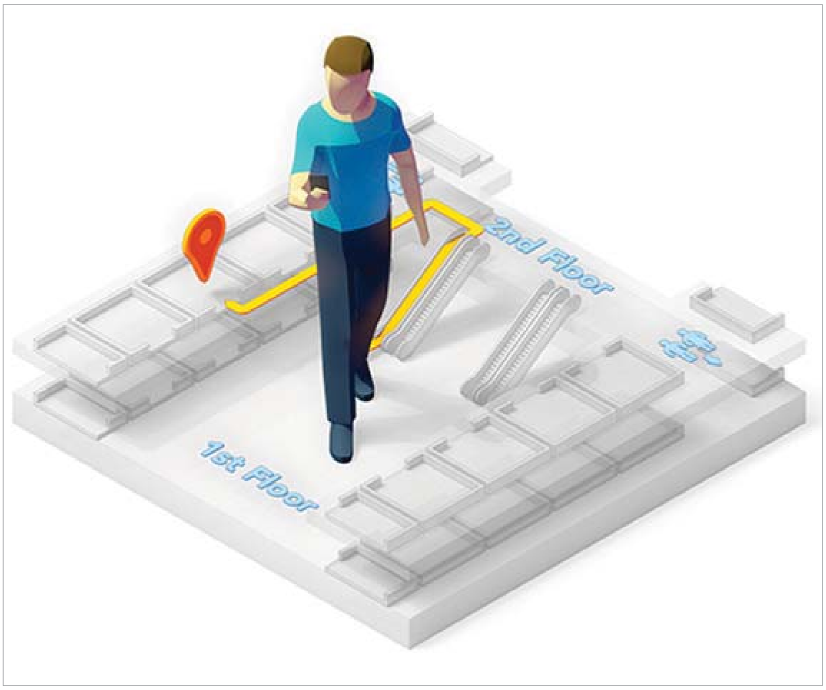
One of the most noteworthy features of UWB over other RF technologies is the extra security it brings against common relay station attacks, where an attacker pretends to be closer to, say, a payment terminal, but in actuality is farther away. For UWB, security features are directly defined in the physical-layer (PHY) circuit used to send and receive packets of data, including cryptography, random number generation, and other techniques to prevent these attacks. Equipped with these capabilities, the technology is well-poised to make a considerable difference to smart retail operations.

To grow the UWB ecosystem and demonstrate the capabilities of fine-ranging technology, an industry coalition called the FiRa Consortium was founded by a group of industry leaders, including NXP, to promote and set standards for UWB technology. The industry consortium is committed to the widespread adoption of interoperable UWB technologies through compliance and certification programs.

CONTACTLESS ENTRY, 24/7

Today's secure access technologies typically require users to open a doorway by entering a code on a keypad, scanning a palm-print, or tapping a badge on a reader. With UWB set up correctly, the self-service store entrance will open automatically and completely without contact as the customer approaches. A UWB solution can track a shopper's approach, instantly verify security credentials, and let them pass through for convenient and secure entry and exit.

To make the setup more efficient, and prevent needless opening and closing, operation can be configured with various parameters. Examples include not opening if the person turns away from the door before they reach a certain point, or if they simply stand within a certain distance of the entrance. This is because UWB technology knows if someone is approaching or leaving, and it understands what side of a door they are on. Therefore, the lock and unlock functions happen at the right times, in response to movements and positioning.



1. Two UWB-enabled devices can also share ranging and positioning data, making it possible for two friends with mobile phones to locate each other with precision.

Once inside the store, a 360-degree UWB-positioning point-of-sale (POS) system can enable a shopper to securely pay for items without taking their phone out of their bag or pocket.

Easily accessible UWB-enabled devices such as mobile phones will become the key to locking or unlocking doors securely, eliminating the pitfalls of physical keys and other access systems. When battery power is running low, interoperable contactless technologies such as near-field communications (NFC) can also be used as a backup.

LOCATION, LOCATION, LOCATION

Satellite-based GPS services are a familiar technology, especially when traveling or navigating outdoor trails. But certain environments make it hard to acquire or maintain a GPS signal, especially when inside a building or a heavily built-up area.

UWB technology brings GPS-style positioning functionality, with pinpoint accuracy, to indoor environments. This precise positioning to within 10 cm, even in crowded, multipath signal environments, makes it easier to navigate large spaces, such as shopping malls, department stores, and large grocery stores. Using UWB, a shopper may be able to navigate their way to an available parking bay, a specific item on a shelf, or even the nearest free bathroom.

Two UWB-enabled devices can also share ranging and positioning data, making it possible for two friends with mobile phones to locate each other with precision *(Fig. 1)*.

Instead of using today's computer-vision technologies, high-precision positioning could be used to monitor foot traffic, alerting the retailer when checkout lines are long or where store layout and stock placement may need adjustment. Following the guidelines that users specify for sharing their data, advertising displays could present tailored content and offers based on the people nearby, or even play a medley of the customers' favorite songs *(Fig. 2)*. Entertainment

2. Instead of using today's computer-vision technologies, high-precision positioning could be employed to monitor foot traffic, alerting the retailer when checkout lines are long, or even play a medley of the customers' favorite songs.

venues can personalize recommendations and advertisements during events.

THE FUTURE OF THE SMART RETAIL ECOSYSTEM

Although the retail industry as a whole is characterized as one that's in a state of constant change, current circumstances have ushered in sweeping modifications as an urgent necessity. Although some might see the hurried migration to online shopping as a threat, the innovators will view this moment as an opportunity to enhance customer offerings, streamline operations, and engage with customers in new and exciting ways.

More retailers are listening to the call for Smart Retail solutions and appreciate that they need support and guidance to implement them as painlessly and efficiently as possible. Advanced technology such as UWB solutions could help eliminate the friction from the in-store shopper journey.

More retailers are listening to the call for Smart Retail solutions and appreciate that they need support and guidance to implement them as painlessly and efficiently as possible. Advanced technology such as UWB solutions could help eliminate the friction from the in-store shopper journey.

Many of today's Smart Retail solutions are hardware-dependent and often tied to a fixed location, which doesn't facilitate a truly mobile and seamless experience. UWB technology's ability to deliver unprecedented accuracy and security when measuring the distance to a target or determining position is unique, offering many possibilities to make today's retail applications easier to develop and more consumer-friendly. With any luck, it will also transform how people shop and pay for consumer goods in ways that perhaps the industry hasn't yet even imagined. mw

REFERENCE

1. https://www.detailonline.com/insights/blog/online-shopping-will-continue-to-have-a-big-share-of-total-retail-sales-post-covid-19/

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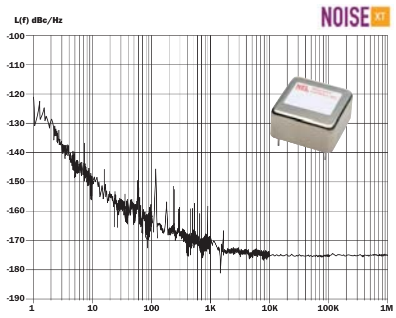
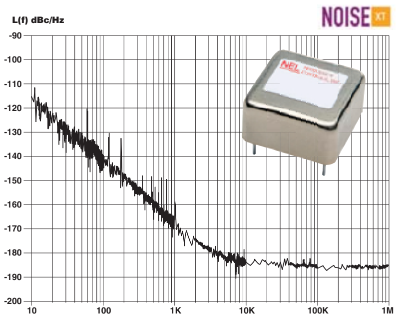
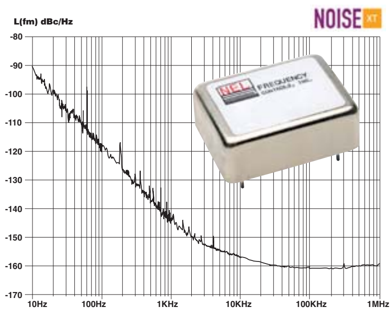


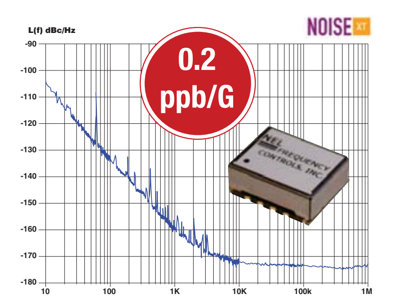
100 MHz Output Frequency



1 GHz Output Frequency

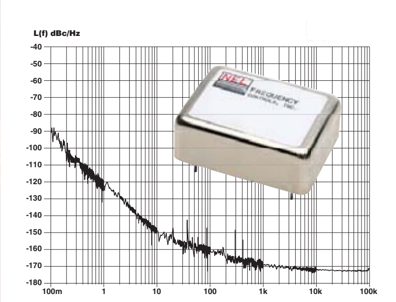


ULPN TCXO @ 100 MHz with Low G Sensitivity



0.2 ppb/G

Precision Europack ULPN OCXO @ 10 MHz



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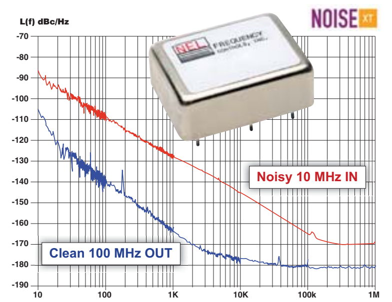
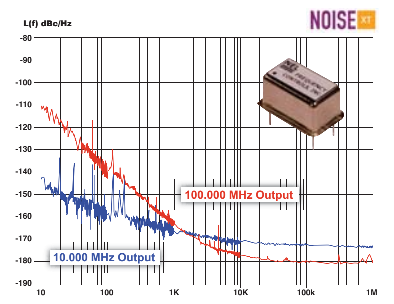


DIP 14 OCXO— 10 MHz or 100 MHz



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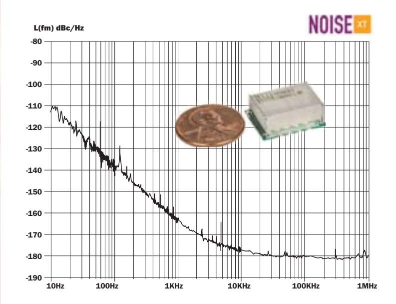

Miniature 14 x 21 x 7.5 mm package

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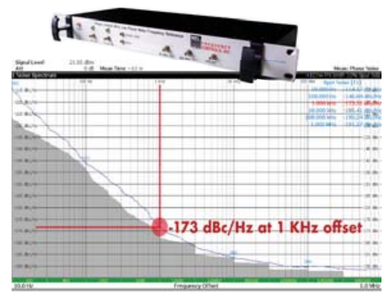

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Phased-Array Antenna Patterns (Part 3)—Linear-Array Beam Characteristics and Array Factor

Part 3 of this six-part series covers beamwidth, combining element and array factors, and antenna plots.

In Part 1 (July *Microwaves &RF*), we covered beam direction and working with a uniformly spaced linear array of antennas. Part 2 in last month's issue focused on antenna gain, directivity, and aperture, as well as array factors. In Part 3, we'll dive into beamwidth, combining element and array factors, and antenna plots.

BEAMWIDTH

Beamwidth provides a metric of angular resolution for antennas. Most commonly, beamwidth is defined by either the half-power beamwidth (HPBW) or the null-to-null spacing of the main lobe (FNBW). To find the HPBW, we move 3 dB down from the peak and measure the angular distance *(Fig. 1)*.

Using our normalized array-factor equation, we can solve for this HPBW by setting Equation 1 equal to the half-power level (3 dB or $1/\sqrt{2}$). We'll assume mechanical boresight ($\theta = 0^o$), N = 8, and d = $\lambda/2$.

$$1/\sqrt{2} = \frac{sin\left(8\left[\frac{\pi\lambda}{2\lambda}sin(\theta) - \frac{\Delta\Phi}{2}\right]\right)}{8\ sin\left(\frac{\pi\lambda}{2\lambda}sin(\theta) - \frac{\Delta\Phi}{2}\right)} \qquad (1)$$

Then solving for $\Delta\Phi$ gives 0.35 rad. Use Equation 2 and solve for θ:

$$0.35 = \frac{2\pi\lambda sin\theta}{2\lambda} \rightarrow \theta = 0.11 \text{ rad} = 6.4° \qquad (2)$$

That θ is the peak to 3 dB point, which is half of our HPBW. Therefore, we simply double it to arrive at the angular distance between the 3-dB points. This results in an HPBW of 12.8°.

We could repeat this for an array factor equal to 0 and obtain the first null-to-null spacing angle of FNBW = 28.5°, for the previously mentioned conditions.

For uniform linear arrays, an approximation for HPBW,[1,2] is given as Equation 3:

$$\theta_B \sim \frac{0.886\lambda}{Ndcos\theta} \qquad (3)$$

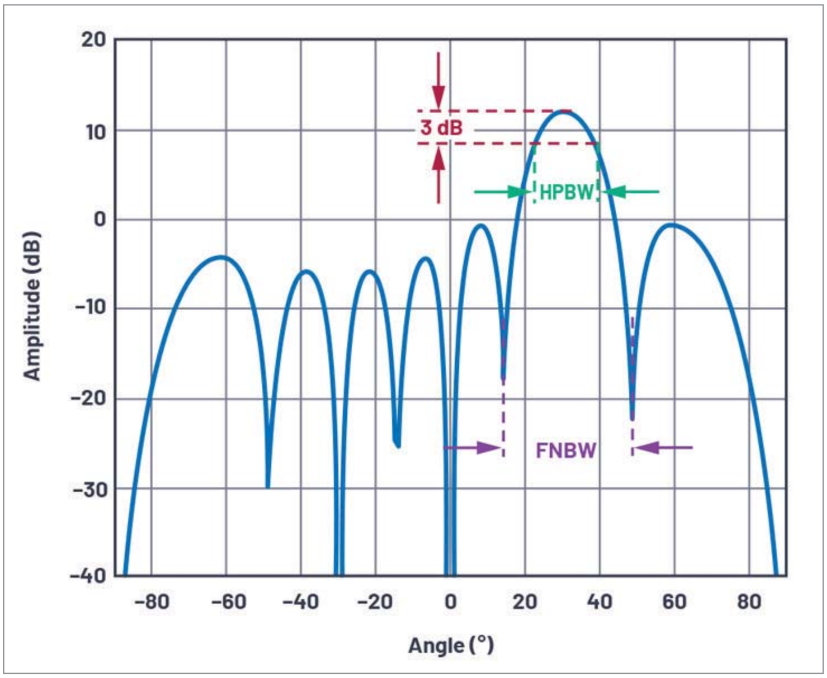
Figure 2 plots beamwidth vs. beam angle for several element counts in the condition of a $\lambda/2$ element spacing. From this graph, it's worth noting some observations relative to array sizes under development in the industry.

A 1° beam accuracy requires 100 elements. If this is desired in both azimuth and elevation, it results in a 10,000-element array. The 1° accuracy is only at boresight under near-ideal conditions. Maintaining 1° accuracy in a fielded array across a variety of scan angles will further increase the element count. This observation then sets a practical limit for beamwidth with very large arrays.

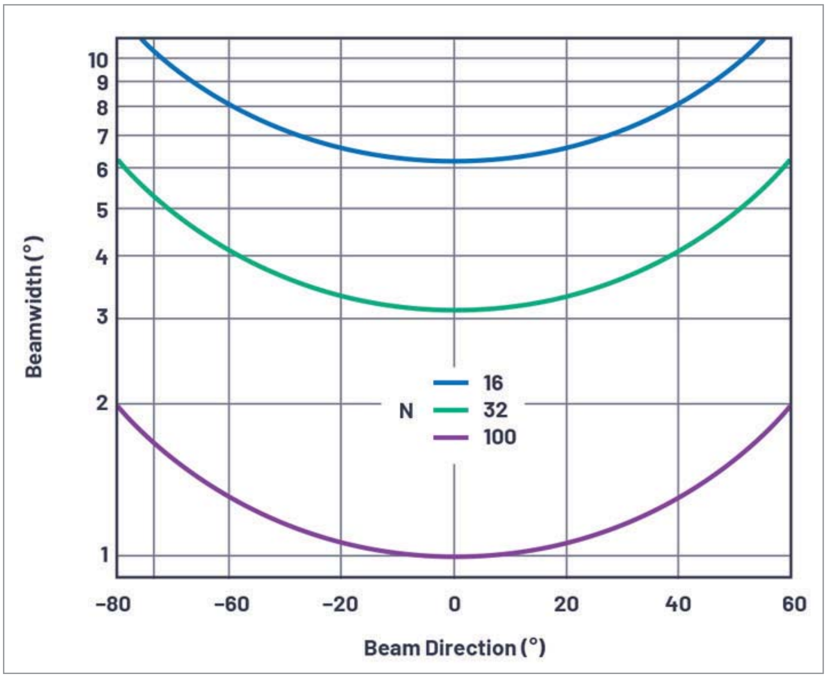
A 1,000-element array is common in the industry. Thirty-two elements in each direction provides an element count of 1024 and can yield a beam accuracy of less than 4° near boresight.

A 256-element array, which can be mass-produced at low cost, can still have a beam-pointing accuracy of less than 10°. This may be perfectly acceptable for many applications.

Also note that for any of these cases, the beamwidth doubles at 60° offsets. This is from the cosθ in the denominator and is due to the foreshortening of the array; that is, the array appears to be a smaller cross-section when viewed from an angle.



1. Shown is a definition of antenna beamwidth (in this example, a linear array of N = 8, d = λ/2, θ = 30°).



2. This plot shows beamwidth vs. beam angle at an element spacing of λ/2 for an element count of 16, 32, and 100 elements.

COMBINING ELEMENT AND ARRAY FACTORS

The previous section only considered the array factor. But to find the total antenna gain, we also require the element factor. *Figure 3* illustrates an example. In this example, we use a simple cosine shape as the element factor, or normalized element gain, GE(θ). The cosine rolloff is common in phased-array analysis and can be visualized if considering a flat surface. At broadside, there's a maximum area. As the angle moves away from broadside, the area visible reduces following a cosine function.

The array factor, GA(θ), was used for a 16-element linear array, with a λ/2 spacing, and a uniform radiation pattern. The total pattern is a linear multiplication of the element factor and array factor, so in a dB scale, they can be added together.

A few observations as the beam moves off boresight:

- The main beam loses amplitude at the rate of the element factor.
- The sidelobes on boresight have no amplitude loss.
- The result is the sidelobe performance of the overall array degraded off boresight.

ANTENNA PLOTS: CARTESIAN VS. POLAR

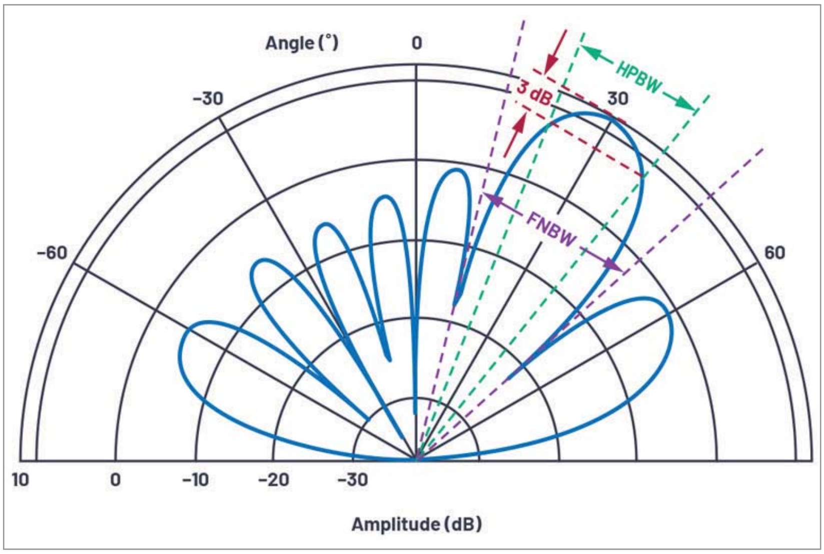
The antenna pattern plots used up to this point have been in cartesian coordinates. However, it's common to plot antenna patterns in polar coordinates as they're more representative of energy radiating spatially outwards from the antenna.

Figure 4 is a redrawn version of *Figure 1* but using polar coordinates. Note that this is the exact same data, point for point—it's just redrawn with a polar coordinate system. It's worthwhile to be able to visualize the antenna pattern in either representation as both are used in literature. For most of this text, we will use cartesian coordinates—in this representation, it can be easier to compare beamwidth and sidelobe performance.

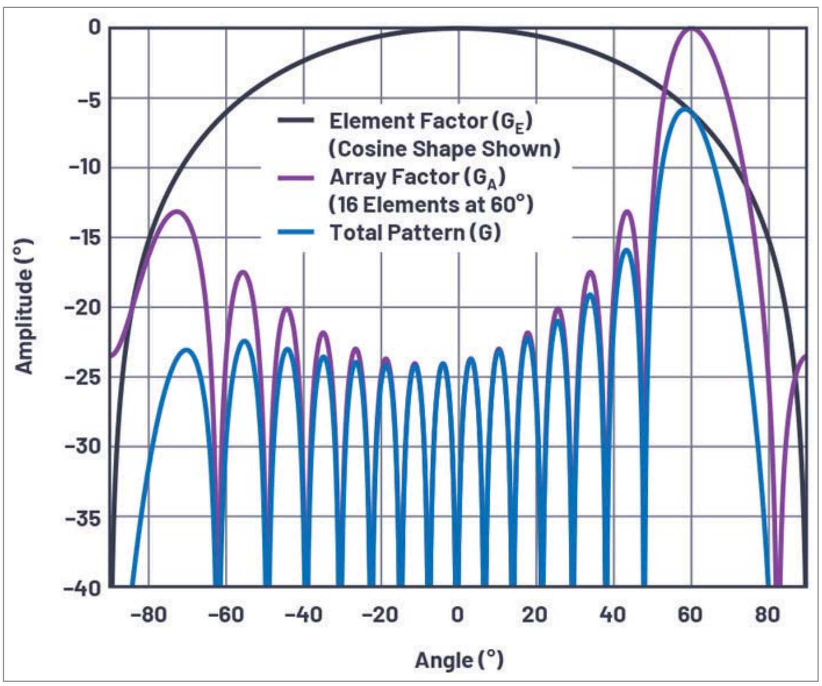
ARRAY RECIPROCITY

Up until this point, all of the diagrams and text have described a signal that the array is receiving. But how would this change for a transmit array? Fortunately, most antenna arrays are reciprocal. Therefore, all of the diagrams, equations, and terminology are the same for transmit as they are for receive.

Sometimes it's easier to think of the beam as being received by the array. And sometimes, perhaps in the case of grating lobes, you may find it more intuitive to think of the array as transmitting a beam. In this article, we generally describe the array as receiving a signal. But if this is harder to visualize, then you can equally think of the same concepts on the transmit side.



3. Element factor and array factor combine to form the total antenna pattern.



4. Shown is a polar coordinate antenna directivity plot for N = 8, d = λ/2, θ = 30°.

SUMMARY

This concludes the first segment of this series. We introduced the concept of beamsteering with a phased array. We derived, and showed graphically, the equations to calculate phase shift across the array for beamsteering. Then, we defined array factor and element factor with observations of how the number of elements, the spacing between elements, and the beam angle impacts the antenna response. Finally, we showed a comparison of antenna patterns in cartesian vs. polar coordinates.

Upcoming articles in this series will further explore phased-array antenna patterns and impairments. We'll study how antenna tapering reduces sidelobes, how grating lobes are formed, and the impact of phase shift vs. time delay in wideband systems. The series will finish with an analysis of the finite resolution of the delay block and how it can create quantization sidelobes and degrade beam resolution. mw

AUTHORS' NOTE: This series of articles is not intended to create antenna design engineers, but rather to help the engineer working on a subsystem or component used in a phased array to visualize how their effort may impact a phased-array antenna pattern.

PETER DELOS is Technical Lead and BOB BROUGHTON is Director of Engineering for Analog Devices' Aerospace and Defense Group; JON KRAFT is Senior Staff Field Applications Engineer at Analog Devices.

REFERENCES

1. Balanis, Constantine A. *Antenna Theory: Analysis and Design*. Third edition, Wiley, 2005.
2. Mailloux, Robert J. *Phased Array Antenna Handbook.* Second edition, Artech House, 2005.
3. O'Donnell, Robert M. "Radar Systems Engineering: Introduction." IEEE, June 2012. Skolnik, Merrill. *Radar Handbook*. Third edition, McGraw-Hill, 2008.

WILLIAM G. WONG | Senior Content Director

MIPI RFFE Version 3.0:
More Precise Timing for 5G Components

The third iteration of MIPI Alliance's RF front-end interface specification is here, and it brings significant technical advances for 5G designers.

Bill Wong, Editor and Content Director, talks with Jim Ross, chair of the MIPI RF Front-End Control Working Group, about how MIPI RFFE v3.0 relates to the ongoing 5G global rollout.

What types of developers would especially welcome the arrival of MIPI RFFE v3.0?

Anyone doing wireless communications and connecting to the 5G network is going to be interested in this new version of MIPI RFFE. In the 2G and 3G communications eras, it was almost strictly mobile applications that were concerned with control of the radio-frequency front end (RFFE). But 5G is bringing widespread change across all wireless communications—across the Internet of Things (IoT), industrial applications, automotive applications, and so on.

In this way, RF control for all of the wireless components that undergird these varied applications is foundational to 5G rollout everywhere. MIPI RFFE already is established as the de facto industry standard for control of the RF front end, so the release of this new version benefits everyone leveraging the 5G network moving forward.

What headaches are these developers experiencing, and how does MIPI RFFE v3.0 help them?

RF front-end system architects benefit from v3.0 because it enables more flexibility by delivering precise timing control of the RF components. Time collisions of multiple RFFE command sequences create a lot of headaches for developers, and now, simultaneously, 5G is bringing about an explosion in the number of RF bands to be managed, and the reconfiguration window has narrowed.

In developing MIPI RFFE v3.0, the working group concentrated on addressing the 3GPP 5G standard where it stands today. So, the new release substantially enhances the interface's triggering features and functionality, and it streamlines and optimizes specifically for today's challenges.

Tell us more about MIPI RFFE's trigger features—what are triggers, and how do they relate to the timing-control requirements of 5G?

Since its initial release, MIPI RFFE has featured triggers, which basically equip the RF subsystem to configure multiple RF devices with very tight timing control. In v3.0, the working group specified more complementary triggers for synchronizing and scheduling register-setting changes. "Timed triggers," "mappable triggers," and "extended triggers" in MIPI RFFE v3.0 work in combination with one another to boost throughput efficiency and reduce packet latency.

Version 3.0 brings a transformational impact on timing precision—a 20X improvement, for example, for back-to-back triggering operations. In this way, the new version of MIPI RFFE enables fast, agile, semi-automated, and comprehensive control of individual RFFE subsystems and delivers against the more challenging timing requirements presented by the Frequency Range 1 (FR1) of traditional sub-6-GHz cellular bands of 5G.

How does v3.0 change business opportunities for RF device vendors, baseband and transceiver vendors, original equipment manufacturers (OEMs), or other users?

The technical advances of RFFE v3.0 allow OEMs and device vendors to quickly migrate to 5G systems without changing the physical layer of the interface. This backward compatibility is crucial. MIPI RFFE already has a large ecosystem of adopters and devices; the interface has been implemented in billions of devices using wireless connectivity worldwide—handsets, smartwatches, automobiles, and more.

What's next for the MIPI RFFE working group?

We are already looking at a number of ideas for the next release of the interface, such as time-stringent RF front-end control for massive MIMO (multiple input, multiple output) and the 5G NR (new radio) FR2 (Frequency Range 2) operating in millimeter-wave (24.25 to 56 GHz) bands, for example. We are always evaluating new features that the user community needs to flourish.

We are currently in the requirements-gathering phase for the next generation of the interface, so this is a great time to get involved. The working group is especially eager for more input from the system or master side of the RF industry, but we welcome contributions from anyone in the industry, anywhere in the world. mw

JIM ROSS has contributed to the MIPI RF Front-End Control Working Group since its inception in 2008 and has served as the group's chair since 2011.

Low-Loss Coaxial Adapter Connects DC to 40 GHz

Mini-Circuits' model SMPM-24M+ is a 50-Ω SMP male (snap-on) to 2.4-mm male coaxial adapter with low loss and low VSWR across a wide frequency range of dc to 40 GHz. The typical insertion loss is 0.11 dB at 1 GHz, 0.31 dB at 20 GHz, and 0.56 dB at 40 GHz The typical VSWR at the SMP male connector is 1.02:1 at 1 GHz, 1.09:1 at 20 GHz, and 1.26:1 at 40 GHz. The typical VSWR at the 2.4-mm male connector is 1.02:1 at 1 GHz, 1.08:1 at 20 GHz, and 1.18:1 at 40 GHz. The adapter's SMP connector reaches full detent for connection with 9 lbs. force and de-mates with 7 lbs. force. The RoHS-compliant coaxial adapter is 0.82 in. long with a 0.28 in. diameter and has a rugged passivated stainless-steel body. It has an operating temperature range of -55 to +100°C.

MINI-CIRCUITS, https://www.minicircuits.com/WebStore/dashboard.html?model=SMPM-24M%2B

Silicon Beamformer ICs for Ku- and K/Ka-Bands Arrive

Anokiwave now offers its latest generation of Ku- and K/Ka-band silicon beamformer ICs for flat-panel, electronically steered antennas. These second-generation satcom ICs are quad-channel, dual-polarization devices that enable phased-array active antennas to be operated with improved performance, reduced cost, and simplified thermal management. The ICs are for antennas serving LEO/MEO/GEO and satcom-on-the-move applications. They have been tested and are in use on multiple live satellite links.

ANOKIWAVE, www.anokiwave.com/satcom/index.html

Signal Generators Span 9 kHz to 6 GHz with High Signal Accuracy and Purity

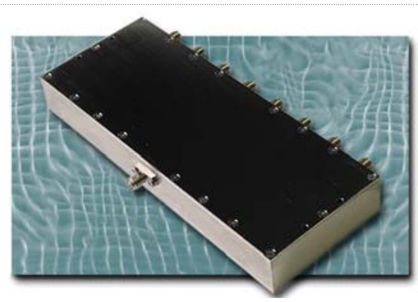
Siglent has released a new series of signal generators that produce analog and vector signals at a frequency range of 9 kHz to 4 GHz/6 GHz with a 0.001-Hz frequency-setting resolution. The SSG5000X series offers superior performance in phase noise, spectral purity, bandwidth, EVM, and output power, while the -V models feature an internal IQ-modulation generator and waveform playback function, making it a breeze to create complex waveform types. The SSG5000X series is outfitted with a 5-in. color touchscreen and produces a maximum output power of +26 dBm with a phase noise of -120 dBc/Hz (at 1 GHz, 20-kHz offset). The ARB model can be utilized to play back digital communication waveform files, while the Custom Mode on the -V versions can generate IQ-modulated signals, including QAM, PSK, ASK, and FSK, with sample rates up to 120 Msamples/s.

SIGLENT, www.siglentna.com/rf-generators/ssg5000x-series/

Eight-Way Power Divider Delivers 10 W from DC to 6 GHz

Broadwave Technologies has introduced its new Model 151-285-008, an eight-way power divider that has an average 10-W power rating. The 50-Ω divider offers a frequency range from dc to 6 GHz with a 1.50:1 maximum VSWR and ±1.6-dB nominal insertion loss above theoretical. It can also operate in wide-ranging temperatures from -20° to +100°C and comes equipped with female SMA RF connectors, but can be reconfigured to use BNC, N, and TNC if needed.

BROADWAVE TECHNOLOGIES, www.broadwavetechnologies.com



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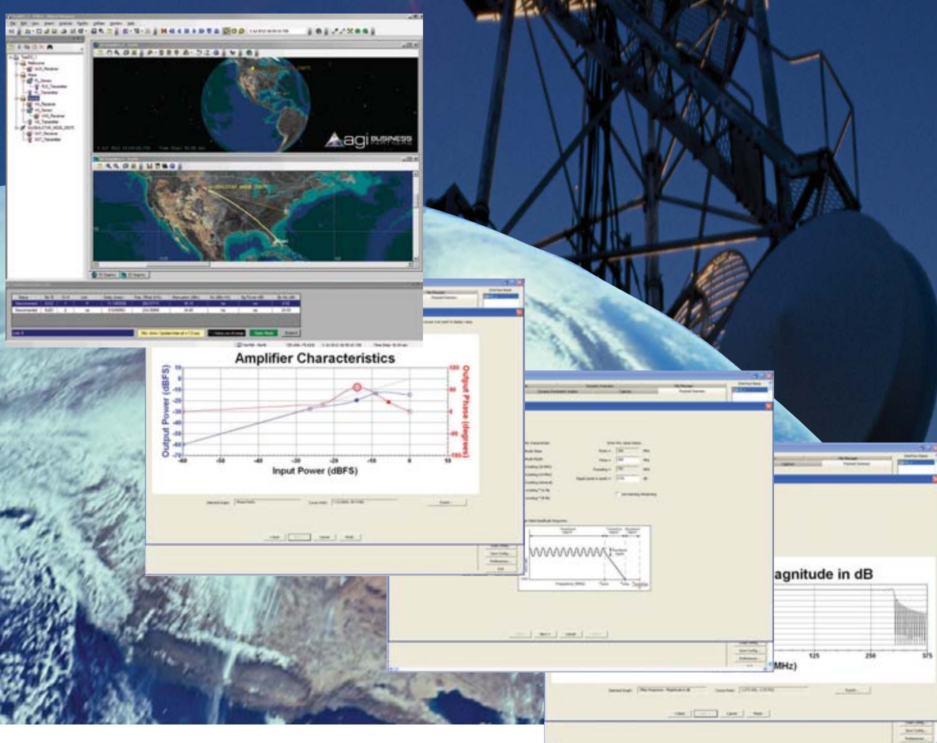

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