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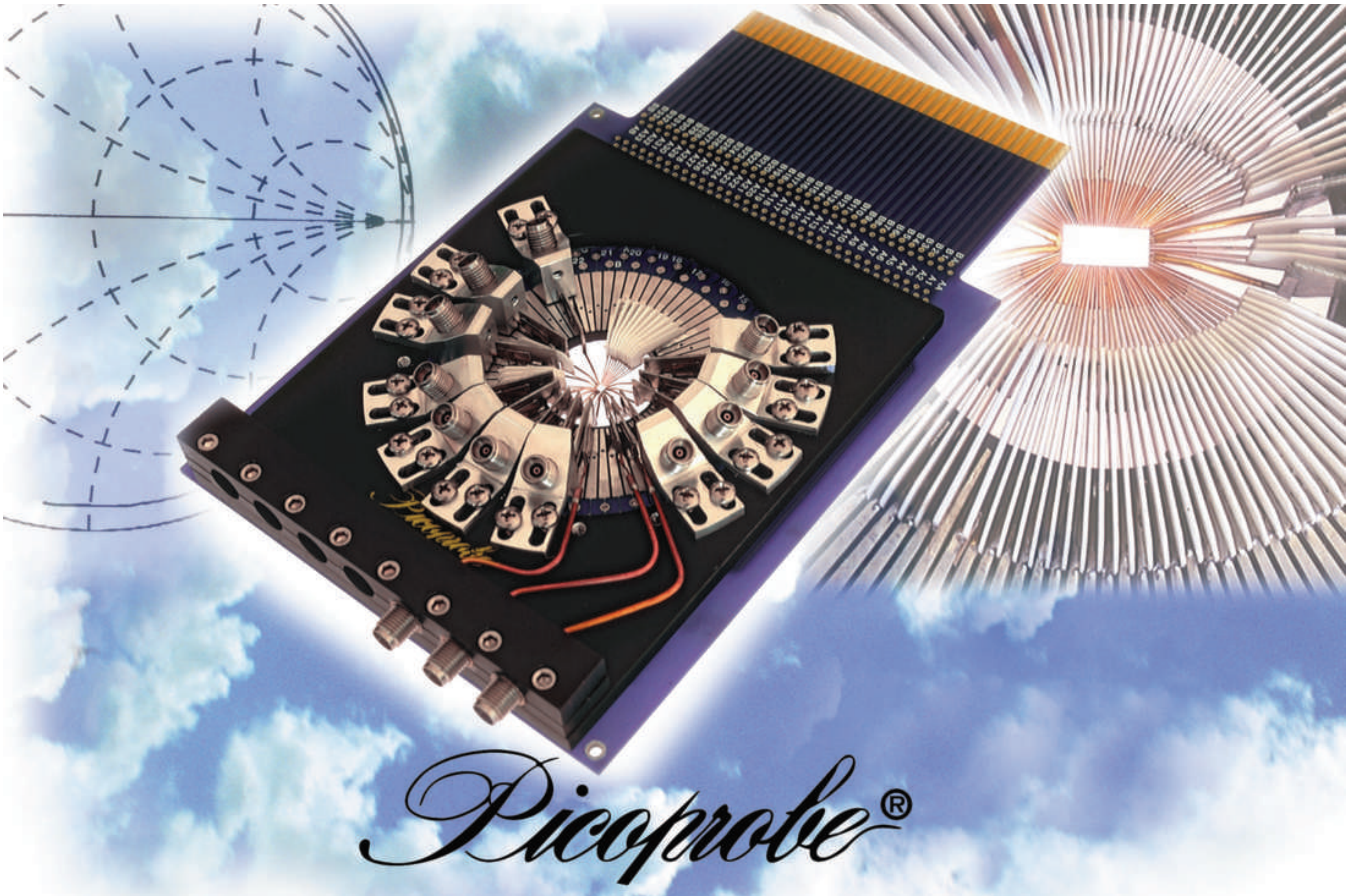

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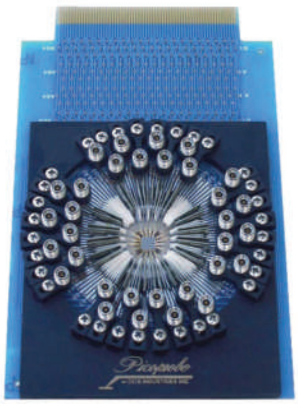

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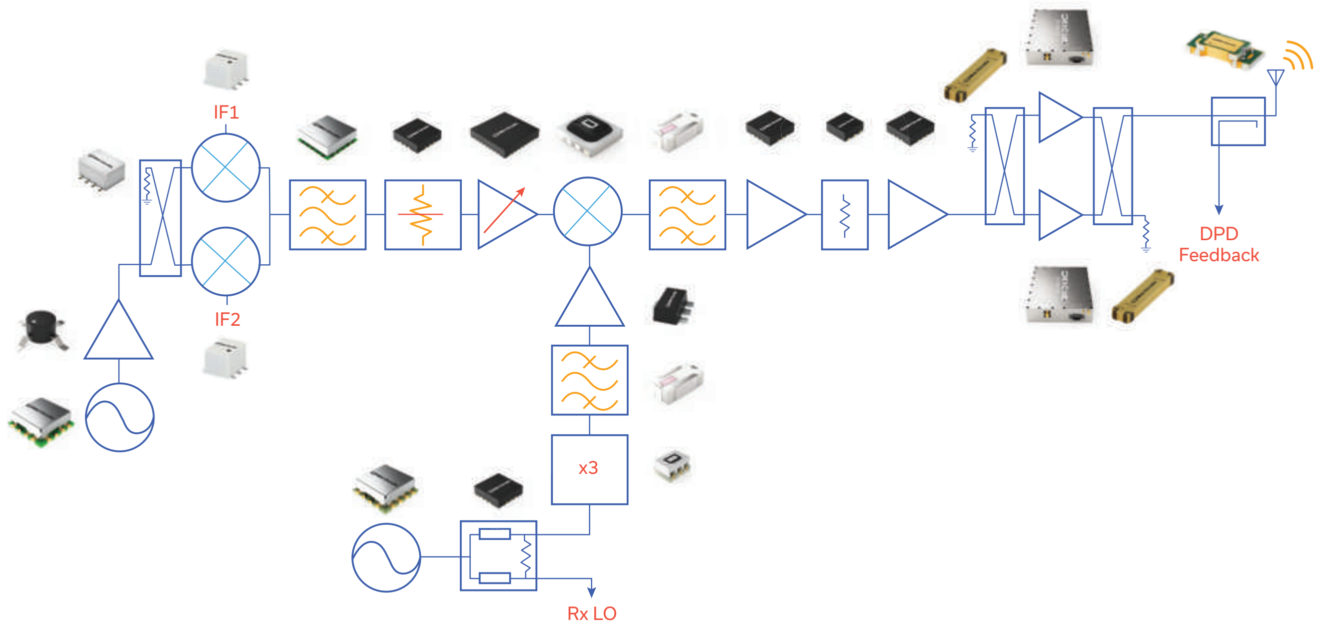

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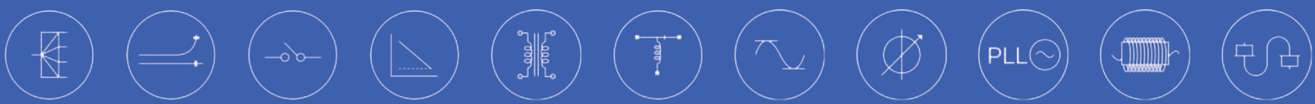

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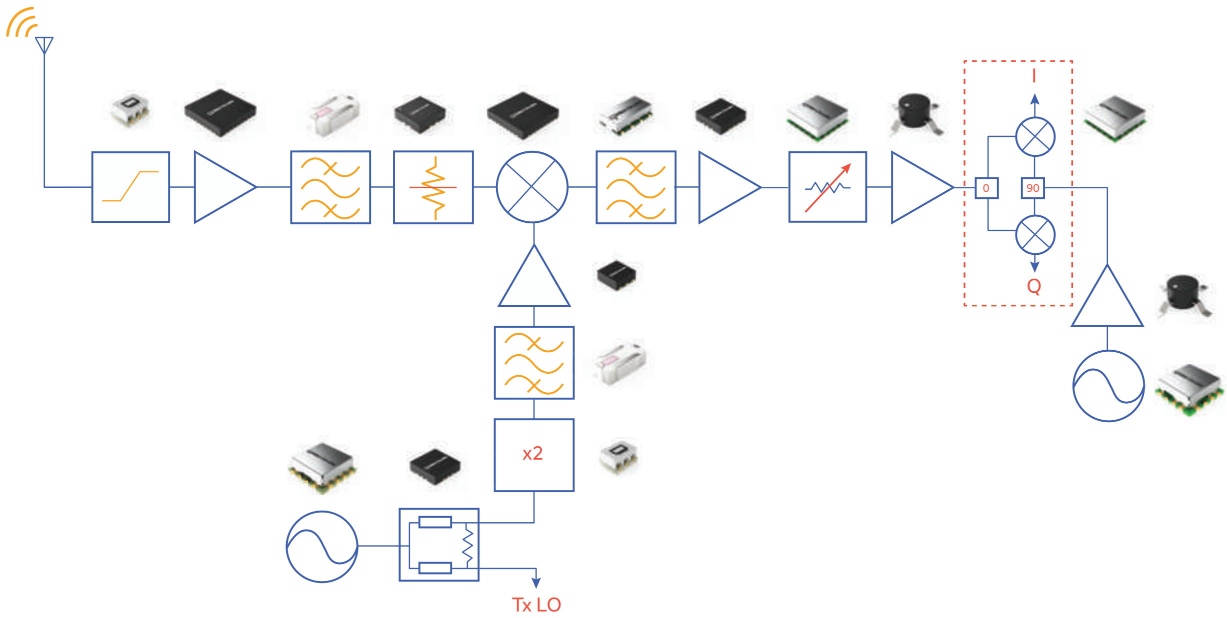

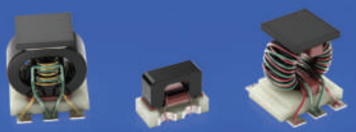

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CONTENTS

February 2023
Vol. 66 • No. 2
Satellite & Radio Communications
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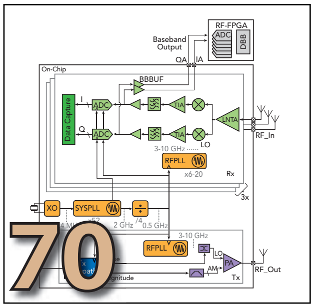

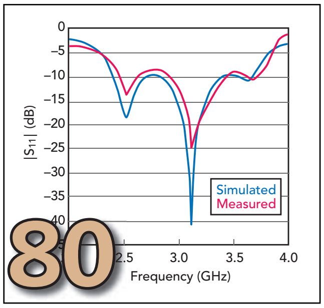

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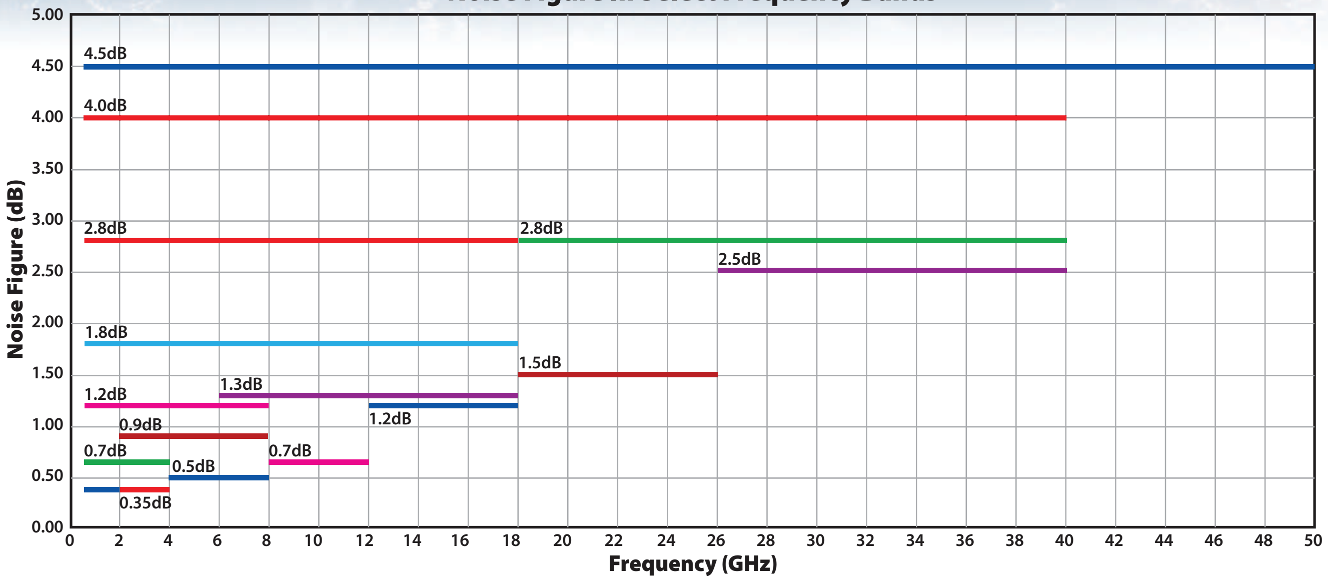

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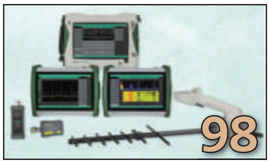

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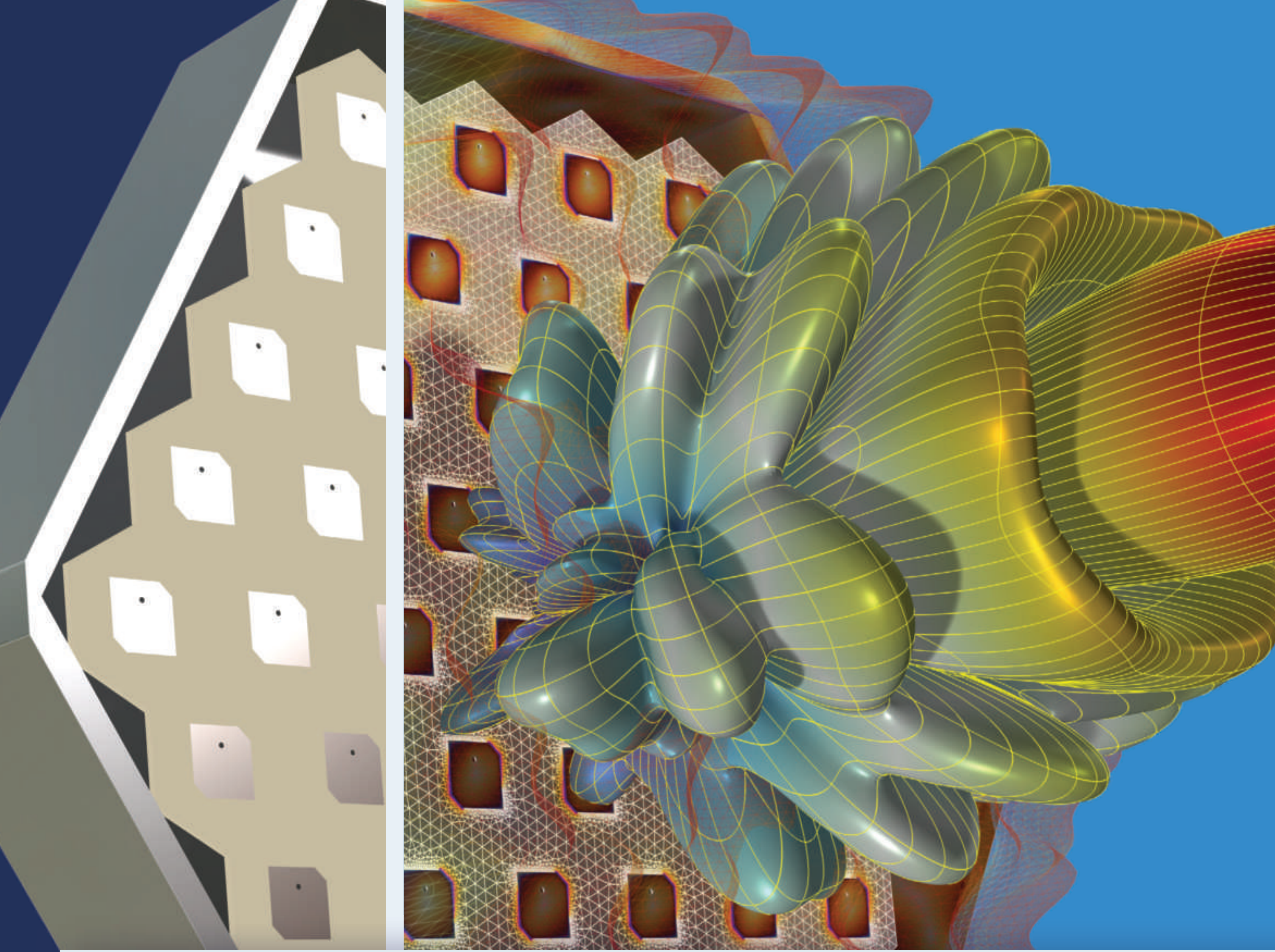

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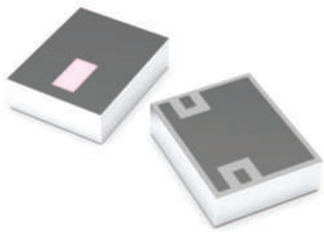

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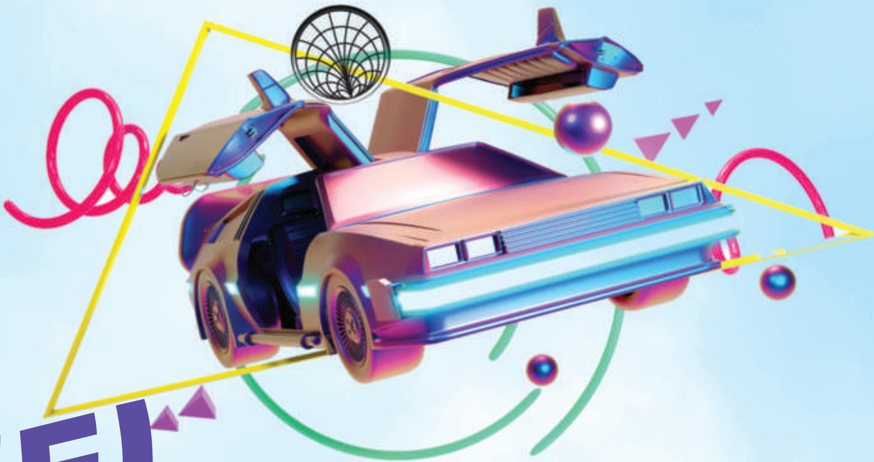

TIME TRAVEL

Stefano Maddio
University of Florence, Florence, Italy

"The Most Beautiful Woman in the World" and the "Bad Boy of Music" Invented Spread Spectrum Technology

Hedwig Eva Maria Kiesler, better known as Hedy Lamarr, was a beautiful actress of Hollywood's golden era. Born in Vienna in 1914 into the Jewish upper class, Hedwig began her theatre career at 15, abandoning her engineering studies, in which she was very talented.[1]

When anti-Semitism began to spread in Europe, Hedwig had to flee to the U.S., where she assumed the pseudonym "Hedy Lamarr." Her career quickly took off, starring in dozens of memorable films including "Boom Town"(1940), "Heavenly Body" (1944) and "Samson and Delilah" (1949).

George Johann Carl Antheil was an eclectic American avant-garde composer. Born in 1900 to a Prussian immigrant family in New Jersey, George's career as a musician started in Europe, where he met many important artists including Picasso, Hemingway and Stravinsky. His most famous work was "Ballet Mécanique," a complicated piece based on the mechanical synchronization of sixteen pianos which premiered in Paris in 1926.[2] In the U.S., most of his prolific career was as a Hollywood film score composer. Included among his many films were "Angels Over Broadway" (1940), "Specter of the Rose" (1946) and "In a Lonely Place" (1950).

These two talented stars were destined to work together in the roaring Hollywood years. Indeed, they met in 1940, but their collaboration did not take place in the world of entertainment. Instead, they created the singular patent of a "secret communication system" for the use of radio-controlled missiles, an ancestor of spread spectrum technology.[3] The core idea arose from Hedy's knowledge applied to the synchronization mechanism mastered by George.[4]

Unfortunately, the idea was ahead of its time. Only in 1957, after the introduction of the transistor, was the concept practically feasible. A working version of the device appeared during the Cuban Missile Crisis in 1962. In 2014, Lamarr and Antheil were inducted into the National Inventors Hall of Fame.[5] Not bad for "the most beautiful woman in the world"[6] and the "bad boy of music"![7]

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A Review of the Current Broadband Satellite Communications Market

Whitney Q. Lohmeyer, Phillip Post, Katie Fleming, Celvi Lisy, Argyris Kriezis and Abby Omer
Olin College of Engineering, Needham, Mass.

Since 2012, the broadband satellite industry has evolved at an unprecedented and unfathomable rate. This article discusses the major historical milestones, system developments and challenges of the past decade, focusing primarily on constellations in non-geostationary (NGSO) low Earth orbit (LEO), while also mentioning developments in the geostationary (GSO) sector.

An April 2022 study conducted by researchers in the Olin Satellite + Spectrum Technology & Policy (OSSTP) Group found that more than 20 unique entities have filed U.S. Market Access applications with the Federal Communications Commission (FCC) for a total of 70,000 fixed satellite service (FSS) satellites operating across Ku-, Ka- and/or V-Bands.[1] Of these systems, several entities (Starlink, OneWeb, Kepler) have started deploying satellites, with OneWeb and Starlink totaling more than 4000 NGSO FSS satellites in orbit as of December 1, 2022, as seen in ***Figure 1***.

Much of the regulatory and technical framework that has enabled these systems to come to fruition was established in the late 1990s or early 2000s for systems like Skybridge and Teledesic. While these 1990s networks were not commercially successful, they moved the satellite industry forward. These efforts helped establish GSO interference mitigation techniques at the International Telecommunications Union (ITU) and refined the processing round filing framework within the FCC. These networks also drove technological advancements like low-cost user terminal antennas, along with gateway and teleport architectures that have been pivotal stepping stones for today's industry.

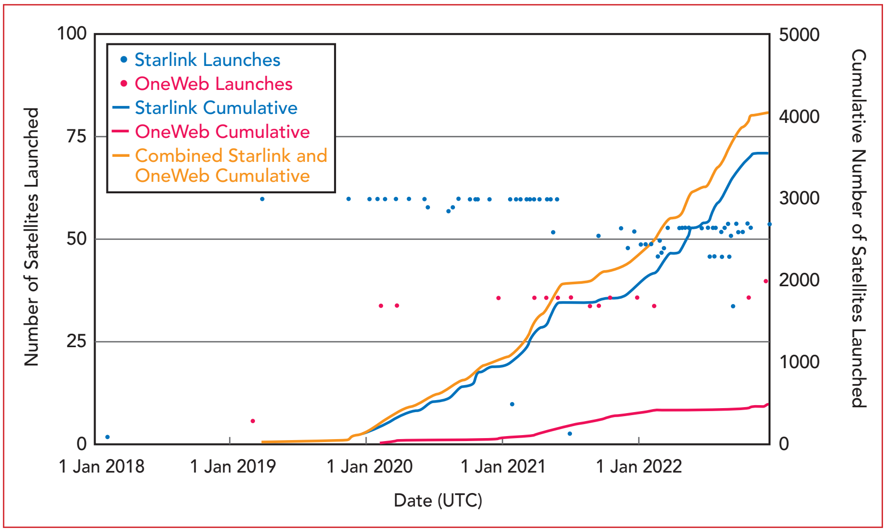

Fig. 1 **Number of U.S. NGSO FSS launches over time.**

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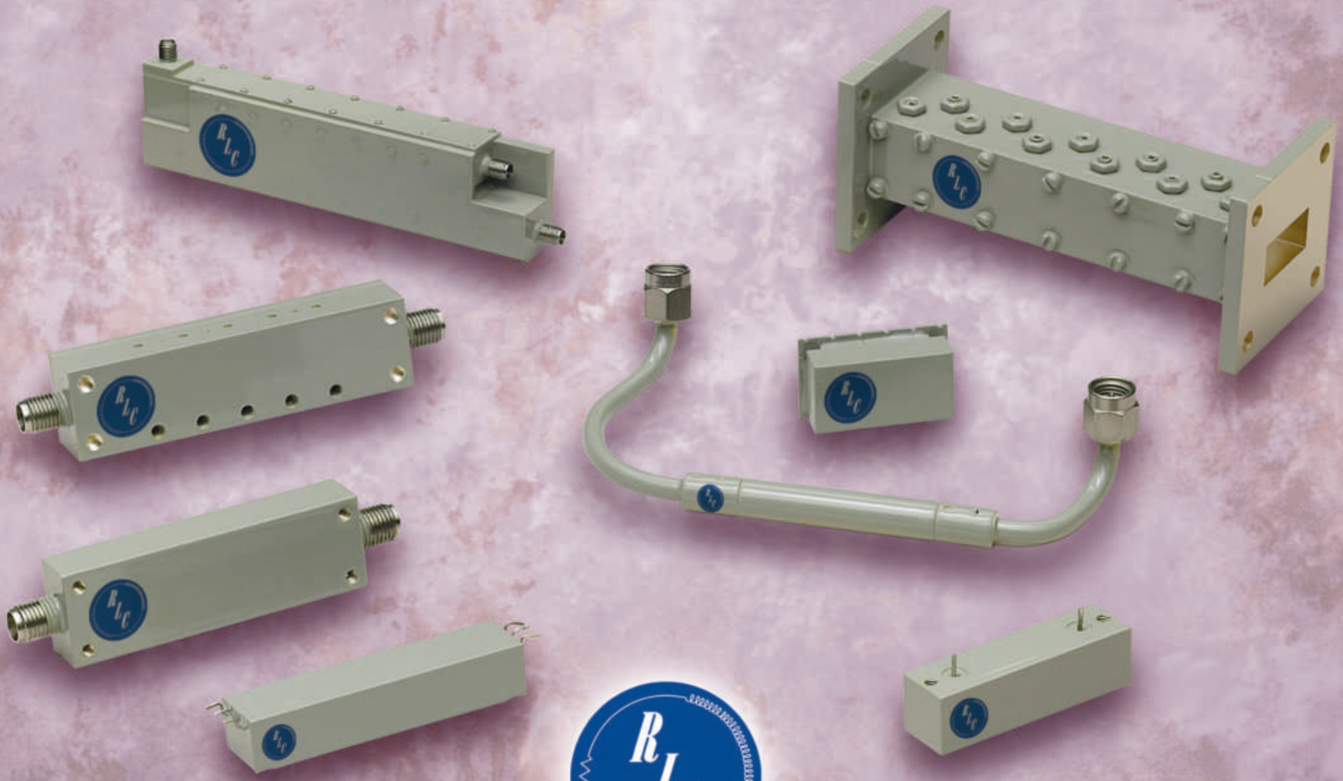

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SATELLITE BROADBAND HISTORY: A DECADAL REVIEW

An assessment of the latest generation of NGSO systems like OneWeb, Starlink, Lightspeed and Kuiper, begins in November 2012 as shown in ***Figure 2***, when Greg Wyler filed for Ku-Band frequencies at the ITU. These frequencies had been studied at numerous World Radio Conferences (WRCs) in the 90s and were set aside for NGSO systems. In this same period, GSO high-throughput satellite (HTS) networks like Viasat-1 and medium Earth orbit (MEO) O3b, also founded by Wyler, were beginning to provide services. O3b was commonly described as the most successful satellite network to that point because it offered high capacity and it had never filed for bankruptcy.

As shown in ***Figure 3***, Wyler brought his NGSO project to Google and for a brief period, he worked with a team in Google's Access Division. After leaving Google and bringing the NGSO FSS project with him, Wyler and Elon Musk collaborated on the constellation effort but later split in 2015 giving birth to today's OneWeb and Starlink constellations.

At WRC-15, studies addressing NGSO protection criteria for GSO systems, referred to as equivalent power flux density (EPFD) limits, were evolving in V-Band along with NGSO bringing into use (BIU) requirements, high altitude platforms (HAPS) frequency allocations and terrestrial frequency allocations for 5G systems. The rules defined at WRC-15 would establish the framework for the future NGSO revolution. The same year, Wyler informed Telesat CEO Dan Goldberg of his LEO broadband constellation plans. Despite being initially opposed to LEO constellations, Goldberg filed through Canada for access to COMMStellation, an existing ITU network. When he was awarded spectrum, Goldberg formed what would eventually become Telesat's Lightspeed NGSO constellation.

This started a rush as mainstays in the satellite industry, new startups and tech conglomerates began filing for NGSO constellations. In 2016, SES found their foothold in this race by acquiring O3b while

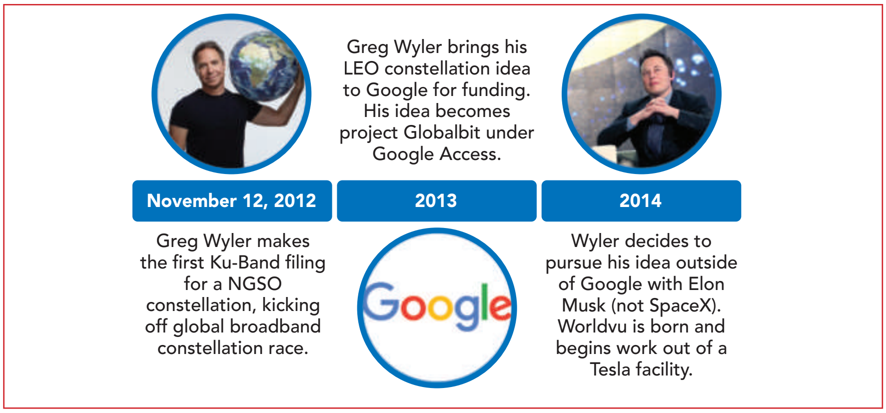

Fig. 2 **Timeline for Greg Wyler's satellite efforts.**

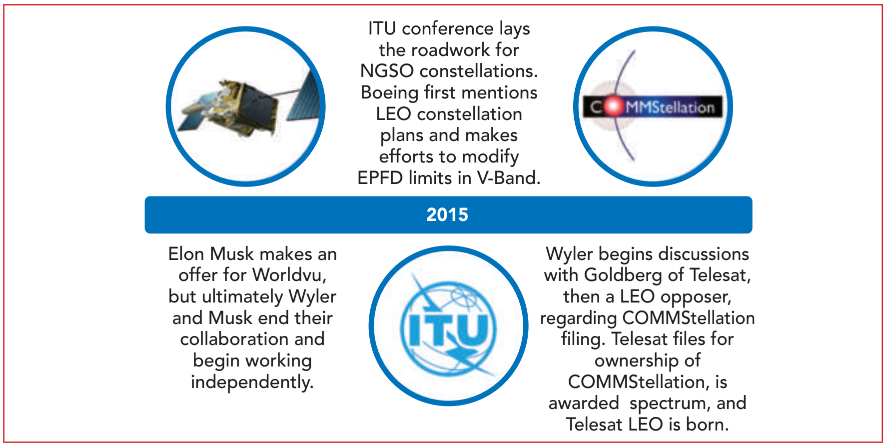

Fig. 3 **The evolution of LEO satellites.**

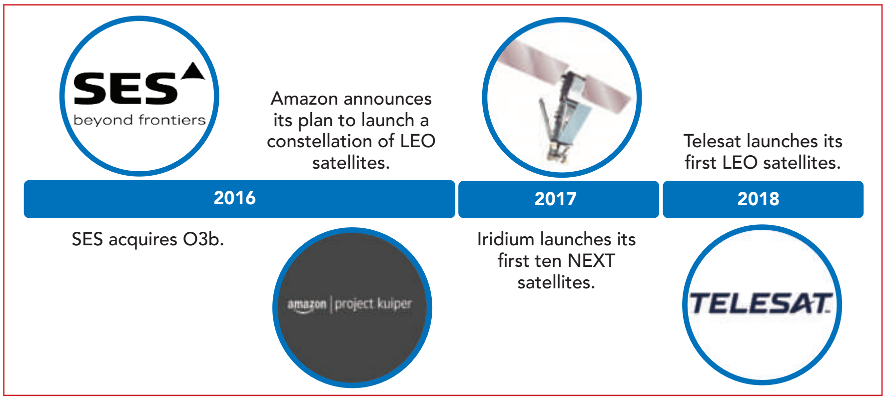

Fig. 4 **NGSO satellite activity after 2015.**

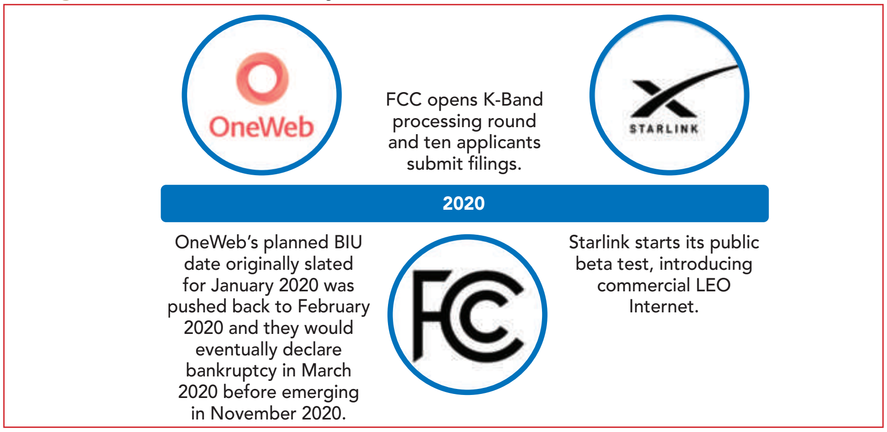

Fig. 5 **The satellite industry speeds up.**

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CoverFeature

Amazon announced their plans to launch the Kuiper constellation of LEO satellites. This is shown in ***Figure 4***.

In 2017, Iridium upgraded their messaging service on their NEXT line of satellites launched through SpaceX. Despite some early success, LEO constellations were not without risk. Greg Wyler's OneWeb, one of the largest players in the new landscape, declared bankruptcy in March 2020 due to funding uncertainties, but emerged from bankruptcy eight months later in November 2020. OneWeb managed to find new funding and they emerged from bankruptcy in November 2020, as shown in ***Figure 5***.

In May 2020, the FCC announced the Ka-Band processing round with ten applicants filing for LEO constellation access. SpaceX also announced its public beta test in October 2020, introducing fast, low latency LEO internet for the masses.

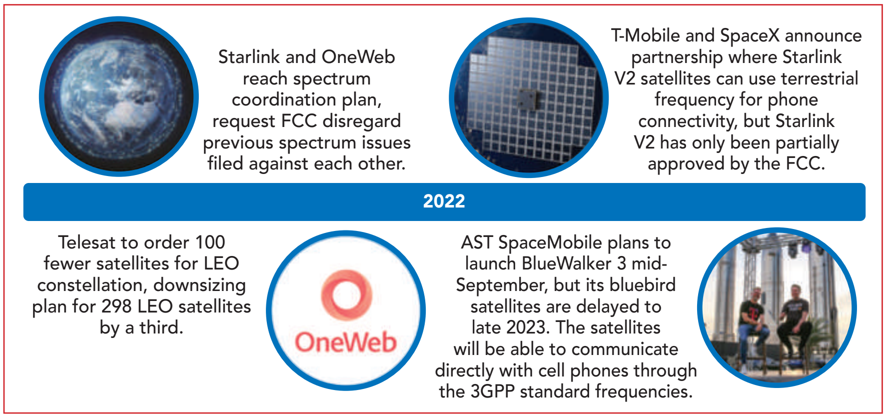
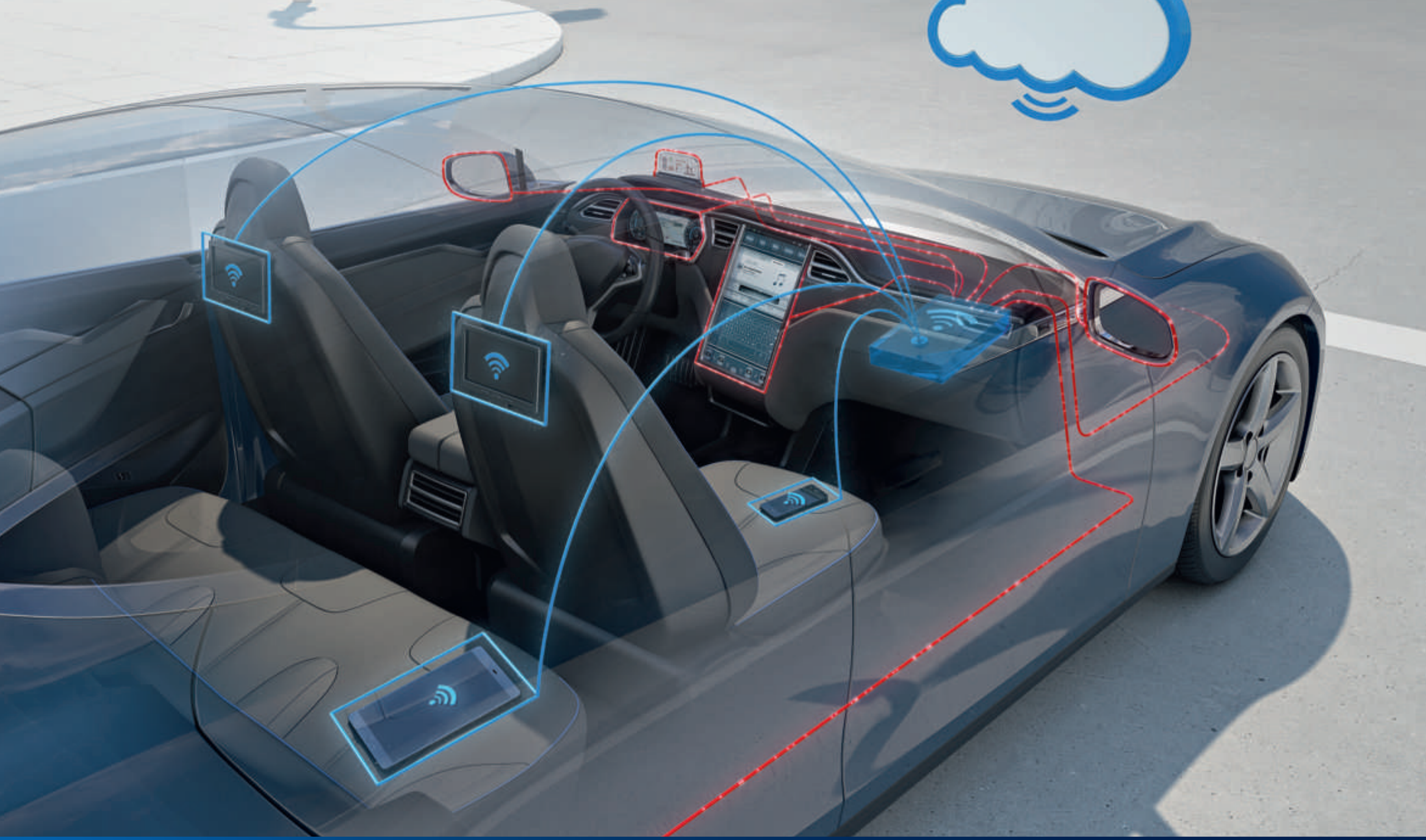


Fig. 6 **Recent developments in the satellite industry.**

TABLE 1

SUMMARY OF SEVERAL LEO, MEO AND GEO SYSTEM STATISTICS AS OF DECEMBER 3, 2022

	Mission Lifetime (Years)	*Altitude (km)*	*Frequency Bands*	*No. of Planned Satellites*	*No. of Orbiting Satellites*
SpaceX Starlink	5-7	328.3 - 614	Ku Ka E	>30,000	3347(2)
OneWeb	10	1200	Ku Ka	47,844	428(3)
Telesat Lightspeed	10	1000-1325	Ka	198	2
Amazon Kuiper	7	590-630	Ka	3236	0
SES O3b	10	8062	Ka	20	20
SES mPower	12	8062	Ka	11	0
Mangata	10	6400 1215-3800 9000-11,585	Ka V	0	791
ViaSat	15	35,786 (GEO) 8400 1300	Ka V	3	
EchoStar	15	35,786 (GEO)	Ku Ka S	9	
Intelsat	15+	35,786 (GEO)	Ku Ka C	50	
Inmarsat	15	35,786 (GEO)	Ka L S	14	



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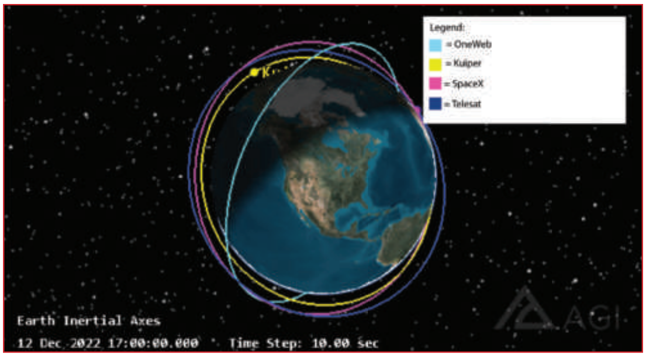

Fig. 7 **Orbital representation of satellite constellations in LEO.**

Even with its inherent risks, the NGSO satellite industry was expanding and evolving at a rapid pace.

In 2021, this pace continued with Canada committing $1.15 billion to Telesat's NGSO Lightspeed Constellation. But 2022 brought challenges to the satellite industry. The COVID-19 pandemic had already created logistical headaches and the war in Ukraine compounded these challenges. Telesat responded by decreasing their LEO satellite fleet by a third and OneWeb experienced launch delays.

Despite the headwinds, the industry experienced several noteworthy accomplishments; Starlink and OneWeb reached a spectrum coordination agreement and Starlink and AST announced plans for low-data rate (not broadband) services directly to cell phones with their next-generation satellites. ViaSat and Inmarsat, two of the largest GEO satellite services and broadband providers agreed to merge in a $7.3 billion deal (see ***Figure 6***).

Table 1 provides a summary of the mission lifetime, orbital altitude, number of planned satellites (as submitted in filings), frequencies and current number of orbiting satellites for primary LEO, MEO and GEO players.

To conceptualize the various orbits of these networks more easily, a single OneWeb, Kuiper, SpaceX and Telesat satellite orbit is depicted in ***Figure 7*** using AGI's Systems Tool Kit (STK). ***Figure 8*** adds the Mangata and Kuiper MEO systems to the LEO satellites of Figure 7. ***Figure 9*** adds the geostationary orbit of a satellite like EchoStar, Intelsat and ViaSat, in green, to the LEO and MEO networks of the previous orbital representations.

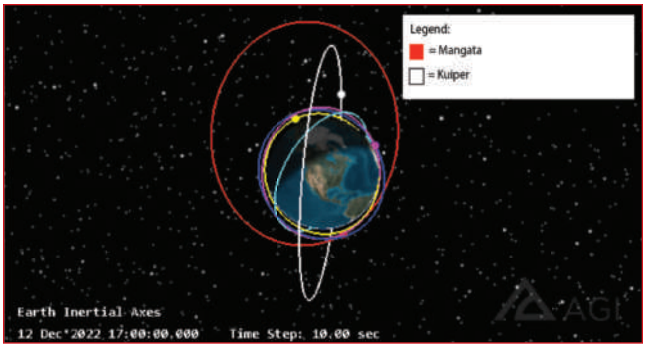

Fig. 8 **Orbital representation of satellite constellations in MEO.**

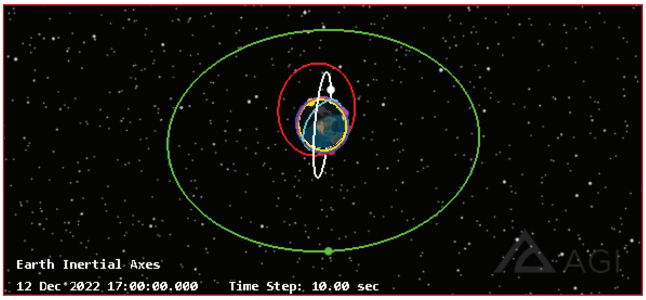

Fig. 9 **Orbital representation of satellite constellations in GEO.**

TECHNICAL AND REGULATORY CHALLENGES

The incredible achievements of the LEO, MEO and GEO broadband satellite sectors over the past decade would not have been possible without overcoming technical and regulatory challenges. The primary technical challenges are the availability of low-cost, user terminals (UTs), efficient solid-state power amplifiers (SSPAs) and launch vehicle supply. The primary regulatory challenges have centered on interference mitigation (EPFD), BIU

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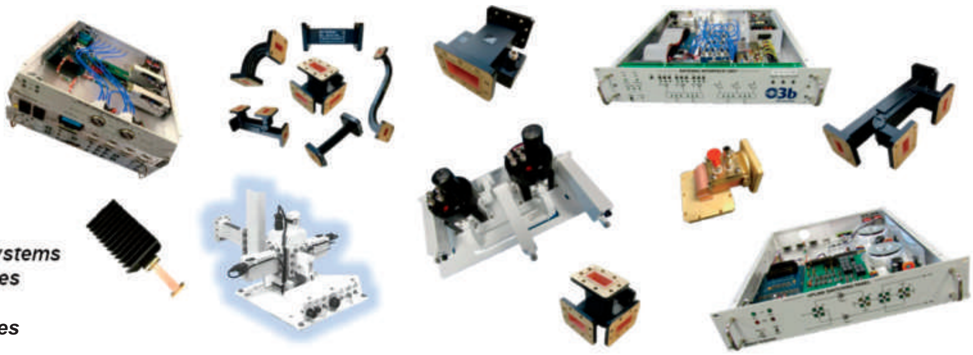

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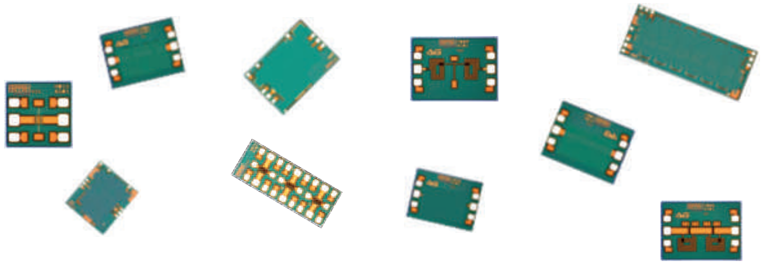
  - Freq: DC-8 GHz, Passband Loss: 2.6 dB, REJ: 20 dB
- *Bandpass Filters*
  - Freq: 7.8 GHz, Passband Loss: 2.2 dB, REJ: 20 dB
  - Freq: 11.75 GHz, Passband Loss: 3.0 dB, REJ: 20 dB
- *Bandpass Filters*
  - Freq: 7.8 GHz, Passband Loss: 2.2 dB, REJ: 20 dB
  - Freq: 11.75 GHz, Passband Loss: 3.0 dB, REJ: 20 dB



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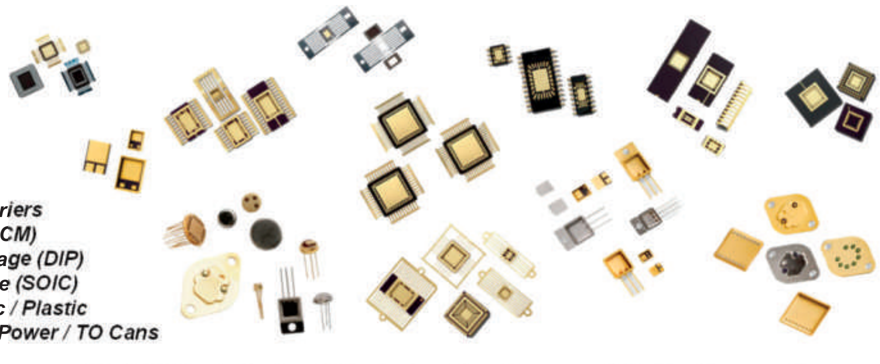
- *PQFN – PQFP – PSOIC / PSSOP*
- *SMD (Surface Mount Devices)*



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deadlines for ITU filings and an update of FCC NGSO licensing rules and sharing frameworks.[4]

TECHNICAL CHALLENGES

Due to tracking requirements for NGSO systems, user terminal technologies consist of a pair of traditional parabolic dishes or a flat panel phased array.[5] While the parabolic dish is less expensive, it requires a second dish to support make-before-break satellite-to-satellite handoffs. The phased array antenna simplifies this process by electronically scanning a single beam or multiple beams, but it is considerably more expensive than the parabolic dish alternative.[6] Starlink is currently selling its terminals at $599 and they are suspected to be selling them at a loss.[7] It is also worth noting that these technologies must comply with ITU and FCC regulations such as power flux density (PFD) limits, earth station gain masks and equivalent isotropic radiated power (EIRP) density limits.[8]

Another critical piece of technology is the SSPA, which is located on the satellite payload. These power amplifier devices have evolved from being largely silicon-based to GaAs and GaN.[9] Over the past few years, we have seen solutions like GaN-on-diamond being developed at companies like Akash Systems.[10] Increasing the efficiency of these devices from today's approximately 30 percent levels to upwards of 50 percent would result in dramatically improved overall system performances, and help close business cases more easily.

The industry is expecting a spike in launch demand starting in 2024, a year in which a potential launch shortage may occur. Out of the four medium and heavy lift launch vehicles available today (SpaceX's Falcon 9, ULA's Atlas V, Arianespace/Roscosmos' Soyuz-2 and Arianespace's Ariane 5), only one is available due to vehicle retirement and U.S. sanctions. Rocket Lab's Electron and Virgin Orbit's Launcher One have successfully delivered payloads to orbit and are expected to be operational with more than ten launches a year by 2024, but these are considered small launchers. The long development time of new vehicles might leave the industry with only one medium-lift launch vehicle able to deliver more than ten launches in a year in 2024. This development poses a major risk to the satellite communications industry and it suggests that a launch supply shortage could lead to higher launch prices and substantial delays that might prevent NGSO systems from achieving their milestone requirements.

REGULATORY CHALLENGES

Satellite systems are governed internationally under the United Nations (UN) via the treaty-based ITU. Every three to five years, the ITU hosts the WRC, which is the culmination of a three-to-five-year regulatory review cycle. During the years between WRCs, working parties (WPs) and study groups (SGs) collaborate to conduct analysis and put forth proposals about topics like spectrum allocation, licensing, interference management and future studies. Country delegations to the WRC consist of national regulators, such as the FCC in the U.S. and Ofcom in the U.K., along with industry players like Intelsat, EchoStar, OneWeb, ViaSat, SpaceX and Amazon and government entities like National Telecommunications Information Administration (NTIA), National Oceanographic Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA).

Over the past decade, international and local regulatory discussions have centered around a handful of topics. High on the list have been interference mitigation techniques for protecting incumbent terrestrial networks via PFD limits and geostationary systems through time-based, statistical EPFD limits.[11] BIU requirements, which define the number of satellites necessary to prevent expiration of an ITU filing. Other important issues for the satellite industry revolve around the terrestrial spectrum allocation for 5G and 6G

technologies, along with coordination rules.

In the U.S., the FCC functions to regulate "interstate and international communications through cable, radio, television, satellite and wire. The goal of the Commission is to promote connectivity and ensure a robust and competitive market."[12] To facilitate spectrum sharing, the FCC authorizes the right to transmit signals over specific bands of spectrum. Unlike terrestrial systems, the FCC implements a processing round approach for satellite spectrum allocation.[13]

FCC processing rounds were held in 2016, 2017, 2020 and 2021, with these rounds alternating to cover either Ku-/Ka-Band or V-Band. Over the course of these processing rounds, more than 20 unique applicants submitted market access requests seeking authorization for over 70,000 total satellites. Since the end of 2019, the FCC has seen the number of NGSO satellites in orbit increase 31.4x with the introduction of FSS NGSO systems. Unfortunately, this unprecedented level of activity has resulted in increasingly long waiting times for FCC approval. The 2016 Ku-/Ka-Band Processing Round took an average of two years from the point at which an operator first submitted their application to the time the FCC made their First Action. In the March 2017 V-Band round, this delay increased by nearly a year to 2.9 years.[1] To address this issue, the House Energy and Commerce Committee introduced bipartisan legislation in the Satellite and Telecommunications Streamlining Act and the Secure Space Act on December 8 to reform FCC licensing rules.[14]

This trend of increasing wait times, coupled with the scarcity of spectrum resources has created a competitive environment among stakeholders leading to questions about how the FCC should consider its sharing rules.[15] Fortunately, some of the major players in the satellite field have reached coordination agreements that allow their current and second-generation broadband networks to coexist. On June 13, 2022, OneWeb and Starlink requested that the FCC dismiss the previous coexistence complaints they had filed against one another and that the Commission instead focus on approving both second round systems as quickly as possible.[16,17] Similarly, on September 24, 2022, Amazon and Telesat reached an agreement.[18]

CONCLUSION

The accomplishments of the satellite industry over the past decade are a true cause for celebration. Given that more than 4000 satellites are operational across Starlink and OneWeb alone, it is likely that these networks will continue to make technological history in the coming decades. However, it is also the case that advances in user terminal, power amplifier and launch availability will be imperative as these networks continue to roll out to ensure financial viability and affordable service offerings. It will also be critical that our national and international regulators continue to

review existing regulations and update outdated policies promptly to encourage innovation and enable new entrants into the sector. ■

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Cliff Drubin, Associate Technical Editor

FlexLink Adaptive Connectivity Solution in Support of U.S. Army's Project Convergence

Raytheon Technologies successfully demonstrated solutions needed to connect defense networks and simplify U.S. Army command and control systems during the Army's Project Convergence exercise.

Key among those technologies was FlexLink, an open-system radio technology developed by the company's Collins Aerospace business that is designed to connect multiple air and ground platforms.

During the exercise, FlexLink was installed on U.S. Army UH-60M helicopters and was able to establish a joint command and control network at distances exceeding 200 nautical miles. The demonstration was key to validating the Army's Project Convergence concept, which is the service's contribution to the Defense Department's (DOD) Joint All-Domain Command and Control initiative.

FlexLink (Source: Raytheon Technologies)

The FlexLink solution is the first open systems radio prototype to be integrated onto U.S. Army platforms. The demonstration bridged four joint service and coalition networks, all operating at different security levels using a multi-level security cross domain solution to enable integrated, connected communication across the battlespace.

"We demonstrated that our ready-now open systems radio can be integrated with existing platforms," said Phil Jasper, president of mission systems for Collins Aerospace. "Providing resilient communications across networks is key for reducing decision-making time and supporting effective operations in any highly contested environment."

FlexLink Adaptive Connectivity Solution for communication, navigation and surveillance delivers resilient network connectivity and assured positioning, navigation and timing to connect the battlespace. The system can operate across a variety of DOD communication networks, from advanced tactical datalinks to legacy narrowband line-of-sight, both wideband and narrowband satcom, high frequency, commercial mesh networking waveforms, as well as emerging directional line-of-sight resilient capabilities. FlexLink was designed using a modular, open systems architecture to allow capabilities to be added or updated quickly and cost effectively.

Europe's Future Combat Air System: On the Way to the First Flight

On behalf of the governments of France, Germany and Spain, the French General Directorate for Armament (DGA) has awarded to Dassault Aviation, Airbus, Indra, Eumet and their industrial partners the contract for the Demonstrator Phase 1B of the Future Combat Air System (FCAS). This landmark contract, amounting to €3.2 billion, will cover work on the FCAS demonstrator and its components for about three and a half years.

This continues the successful Phase 1A demonstrators' related R&T work and development activities, which enabled the identification of key technologies and the launch of the demonstrators' developments. Paving the way for the development phase of the program, this demonstration Phase 1B will allow continuation of flying demonstrators and required cutting-edge technologies development and maturation as well as project architectures consolidation, with in-flight demonstrations targeted in the next phases by 2028-2029.

The program is made up of a set of systems: New Generation Fighters teaming with Remote Carriers and connected through a Combat Cloud. To meet the ambitions and challenges of such a program, an adapted and efficient industrial organization has been set up and built around technological pillars. Each pillar is under the leadership of an industrial champion acting as prime, working in close cooperation with its main partners and leveraging each nation's aeronautical industrial ecosystems.

In addition to their prime role per pillar, Airbus, Dassault Aviation and Indra act as national coordinators to ensure the overall coherence of the demonstrators and the overall program's steering and work consolidation.

The industrial partners thank the three nations for their confidence and reiterate their firm commitment and total mobilization to make this program the armed wing of Europe's strategic autonomy thanks to the reinforcement of the operational, technological and industrial sovereignty of its defense.

FCAS (Source: Airbus Defense and Space)

For More Information Visit mwjournal.com for more defense news.

Bull's Eye: Turkish Combat Drone Akinci Test-Fires New-Gen Guidance Kit

Akinci hit the target with high precision with a 1000-lb. (about 455 kg) MK-83 bomb equipped with the guidance kit named Gökçe after taking off from a flight training and test center in northwestern Tekirdag's Çorlu district.

"Bull's Eye," wrote Selçuk Bayraktar, CTO of Akinci developer Baykar, as he shared a video of the test on Twitter.

Developed by TÜBITAK SAGE, the new generation guidance kit engaged to the target that Akinci illuminated with a laser from an altitude of 20,000 ft. (6096 m), marking its first test on an unmanned combat aerial vehicle (UCAV).

It comes just days after Akinci successfully test-fired Turkey's first air-to-ground supersonic missile, the TRG-230, after hitting a target at a distance of over 100 km (62 miles).

Marking the most advanced and sophisticated drone built by the country, Akinci was first delivered to the Turkish security forces in late August last year. The UCAV joined the company's Bayraktar TB2, which has been widely used and sold to various countries, including Ukraine, Qatar, Azerbaijan and Poland.

Akinci (Source BaykarTech)

Akinci is longer and wider than the Bayraktar TB2 and can perform strategic tasks. The state-of-the-art UCAV Akinci can fly for 24 hours and with a service ceiling of 40,000 ft. (12,192 m). It has a 20-m wingspan with a unique twisted-wing structure and is equipped with a fully automatic flight control and a triple-redundant autopilot system. It has the capacity to carry a load of 1350 kg.

The Akinci will be equipped with a locally made active electronically scanned array radar and air-to-air missiles Gökdogan and Bozdogan and will launch several types of locally made ammo, such as standoff missiles.

Baykar says the Akinci can attack targets both in the air and on the ground. It can also operate alongside fighter jets and fly higher and stay in the air longer than Turkey's existing drones.

Bayraktar TB has been sold to 27 countries so far, while Baykar has signed export deals with five countries for Akinci. Exports constitute almost 98 percent of Baykar's revenues this year. It says it has agreed to more than $1 billion worth of export deals with 18 different countries throughout 2022.


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Cliff Drubin, Associate Technical Editor

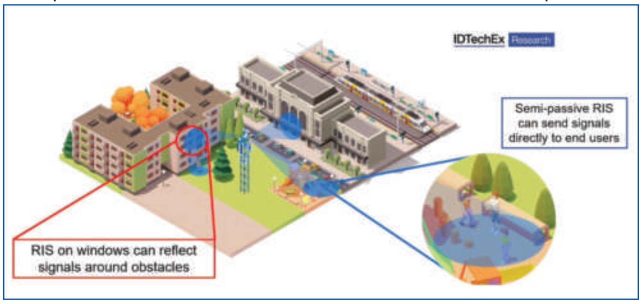
Metamaterials' Potential in mmWave 5G Telecommunications and Beyond

Having been largely confined to the realm of academia for many years, metamaterials are now set for commercialization in several major applications. The IDTechEx report, "Metamaterials Markets 2023-2043: Optical and Radio-Frequency," explores the opportunities within this emerging materials technology.

A particularly significant emergent application of electromagnetic metamaterials is in supporting the deployment of high frequency telecommunications, such as mmWave 5G and even THz. High frequencies can enable faster data transfer and hence improved user experience. However, at high frequencies, there is a severe loss in energy across long distances. These problems can be further exacerbated by obstacles, as is common in urban environments. As a result, a low-power device that can facilitate the delivery of high frequency signals in crowded environments is required.

Metamaterials offer a potential solution through enabling the development of reconfigurable intelligent systems (RIS). These systems integrate electronic components to reflect radio waves in specific, configurable directions—enabling signals to be reflected around obstacles, thus overcoming the issues of signal blockage. RIS can potentially even track users autonomously for directed communications, allowing for greater signal quality and improved security by reducing the likelihood of connection by unauthorized users. These advantages that RIS propose have drawn attention from telecom providers such as Verizon, who partnered with Pivotal Commware in 2020 to deploy the latter's products in supporting mmWave 5G deployment.

If beaming a signal in a specific direction were the only goal, then this could be achieved using conventional relay stations. However, RIS offers two crucial advantages—namely, their low power use and small form factor. This allows them to be deployed at scale in areas where a conventional relay station would not fit, such as above traffic lights at crowded junctions or under a ceiling in a stadium, significantly improving 5G coverage in crowded environments. The requirement of low power also greatly reduces the costs of operating a widespread network, and it may even be possible to power some RIS devices from built-in energy harvesting systems such as solar photovoltaics.



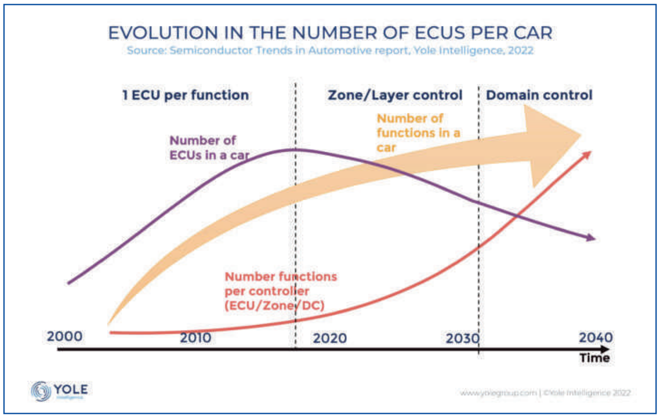
RIS (Source: IDTechEx (PRNewsfoto/IDTechEx Ltd)

Where Does Radar Sit in ADAS Architecture Centralization?

The path through car autonomy is certainly ongoing, with the regular addition of new functions for car autonomy. It started in the 2010s with basic functionalities such as automatic cruise control and advanced emergency breaking, it is currently still in progress with the addition of functionalities such as Highway Pilot, and we expect it will continue in the next years with the addition of functions such as City Pilot, where a car can be fully autonomous in a specific area," said Adrien Sanchez, technology and market analyst, computing and software, at Yole Intelligence.

This has led to the multiplication of sensors and to a growing number of software layers for more accuracy in the understanding of the environment, as well as to the introduction of some redundancy to prevent crashes due to system failure. To handle this growing amount of data and this pipeline complexity, the computing power required has increased dramatically. This has a direct impact on the car architecture, from a decentralized architecture with many small MCUs, to a centralized architecture with a few powerful processors in an ADAS domain controller. Centralization is the next step for sure, with the need to do sensor fusion.

This is no longer about providing range and velocity for a small number of objects. Radar sensors are evolving to literally perceive the scene around the car. The goal is to get a free space mapping by radar only, for obvious reasons of redundancy. With such a sensor, OEMs will have access to path-planning for any time, in any driving scenario. Centralization seems an obvious choice to bridge the gap, as it resonates with resources optimization. But it is also a massive change in archi-



ECUs Source (Yole Group)

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tecture, raising multiple points such as the partitioning of radar signal modulation, data processing, data transport and even data fusion. Meanwhile, as these problems are clarified, edge processing has room for evolving beyond its current capabilities. In any case, the importance of software in radar sensing is growing and multiple industry players are positioning for either one or the other approach. It will be interesting to track how this industry evolves in the next few years.

New Use Cases and Markets for Connected Sensors

Enterprises are increasingly looking to add connectivity to a wide variety of assets. Greater variety of connectivity types, more sensor features and form factors and greater software intelligence is enabling the condition-based monitoring (CBM) market to expand into new use cases and to generate greater value for customers. According to ABI Research, CBM sensors will reach 277 million connections by 2026.

"The CBM market has so far been the preserve of short-range wireless (SRW) technologies," stated Tancred Taylor, IoT markets industry analyst at ABI Research. "Increasingly, however, we are seeing a more neutral stance toward connectivity as adopters approach use cases not from a technology perspective but from an outcome perspective. More investment in software and analytics platforms pushes the focus further toward generating value from sensor fusion and edge data execution. SRW, WAN and wired technologies play different roles in growing the market into new types of assets that can be monitored. These technologies sometimes compete, but they often address distinct use cases. They contribute to expanding what is possible from CBM solutions rather than purely competing on the same turf."

To date, the market is dominated by data collection on utilities and processes and monitoring motor-powered equipment. Much of this activity is happening in the industrial market, where companies are looking to reduce downtime by switching to more proactive maintenance strategies and reduce costs through more efficient use of machine and human resources.

Many companies are addressing the CBM market with a specialist focus on solving specific use cases. Independent solution vendors such as Fluke Reliability, VersaSense, Worldsensing, Everactive and many others are a core part of this ecosystem. Sensor vendors such as Wika or SICK Sensors are increasingly making a mark in their target industries, particularly through evolved software offerings.

Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Akoustis Technologies Inc. announced that it has acquired **Grinding and Dicing Services Inc. (GDSI)**, a U.S.-based provider of premium back-end semiconductor supply chain services. Akoustis' acquisition of GDSI is expected to support a strategy to reshore its packaging of XBAW filters to the U.S. and to support its anticipated application for funding under the CHIPS and Science Act. Akoustis is paying $14 million in cash and $2 million in stock for GDSI, with an additional $4 million in the form of a secured promissory note payable over three years based on key employee retention and agreed upon performance, for a total of $20 million.

Av-Comm Space and Defence announced it has acquired the Central Coast-based large antenna specialist **R G Systems**. Australian-owned R G Systems has been operating since 2005 and during that time has installed and refurbished more than 100 large antenna systems for defense and civil satellite communications customers. This strategic acquisition of R G Systems will expand Av-Comm's technical capability and offer further opportunities for growth at a time when new satellite constellations are proliferating.

L3Harris Technologies and **Aerojet Rocketdyne Holdings Inc.** together announced the signing of a definitive agreement for L3Harris to acquire Aerojet Rocketdyne for $58 per share, in an all-cash transaction valued at $4.7 billion, inclusive of net debt. This marks L3Harris' second acquisition announcement of 2022, demonstrating its continued focus on delivering critical capabilities to warfighters while strengthening the nation's defense industrial base through increased competition. A provider of propulsion systems and energetics to the Department of Defense (DOD), NASA and other partners and allies worldwide, Aerojet Rocketdyne has a 100-year heritage of excellence delivering some of the most significant moments in space exploration and discovery.

Micross Components, a provider of high-reliability microelectronic product and service solutions for aerospace, defense, space, medical, energy, industrial and other applications, announced the acquisition of **KCB Solutions**, a provider of RF and microwave products. The acquisition further expands the proprietary Hi-Rel component products portfolio of Micross. KCB, a privately held company and portfolio investment of Artemis Capital Partners (Artemis), located in Shirley, Mass., has established itself as a best-in-class supplier of highly-engineered, leaded and leadless, GaN/GaAs RF and microwave switches, attenuators, amplifiers, multi-chip and functional modules in both standard and custom form.

COLLABORATIONS

Keysight Technologies announced it has collaborated with **Qualcomm Technologies** to establish an end-to-end 5G non-terrestrial network (NTN) connection. Based on this successful demonstration of call signaling and data transfer using orbit trajectory emulation, Keysight and Qualcomm Technologies aim to accelerate 5G NTN technology to provide affordable broadband connectivity in remote areas. NTNs based on 5G satellite-to-ground communication bring secure, reliable and high bandwidth connectivity to remote areas that do not have terrestrial network coverage.

CEVA Inc., a licensor of wireless connectivity and smart sensing technologies and co-creation solutions, announced that **Autotalks**, a leader in vehicle-to-everything (V2X) communication solutions, has licensed and deployed the CEVA-XC4500 Communication Processor and CEVA-BX1 Digital Signal Controller in its third generation V2X chipsets, TEKTON3 and SECTON3. This latest collaboration follows on from Autotalks second generation chips, SECTON and CRATON2, which are also powered by CEVA DSPs. ABI Research forecasts that the number of registered vehicles with V2X will surpass 61 million by 2030, growing at a CAGR of 53 percent from 2023.

Casa Systems, **Enea** and **IBM** have built a complete private 5G solution that combines best-in-class technology with agility for service providers to deploy, or enterprises to build, Private 5G solutions that are more scalable, dynamically adjustable, reliable and secure. All three organizations are playing a significant role in bringing the Private 5G network to life. Casa Systems' end-to-end 5G wireless solutions portfolio addresses the coverage and capacity needs for today's public and private networks, powered by its Axyom Software Framework.

NEW STARTS

Würth Elektronik is relocating its Munich site from Garching to Freiham. The Hightech Innovation Center Munich (HIC), a state-of-the-art building with a working and test field landscape, has been created on the west side of the metropolis. The new facility offers the latest new-work approaches and space for 250 employees in the first construction phase. True to the company's motto "more than you expect," the HIC is not only an investment in the company's future but also in Munich as a location.

CONTRACTS

The F-35 Joint Program Office and **Lockheed Martin** have finalized the contract for the production and delivery for up to 398 F-35s for $30 billion, including U.S., international partners and foreign military sales aircraft in Lots 15 and 16, with the option for Lot 17. The agreement includes 145 aircraft for Lot 15, 127 for Lot 16, and up to 126 for the Lot 17 contract option, including

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the first F-35 aircraft for Belgium, Finland and Poland. Lot 15-17 aircraft will be the first to include Technical Refresh-3 (TR-3), the modernized hardware needed to power Block 4 capabilities. TR-3 includes a new integrated core processor with greater computing power, a panoramic cockpit display and an enhanced memory unit.

Pole/Zero, part of **Microwave Products Group** and **Dover**, has been awarded a $53,544,462 firm-fixed-price, indefinite-delivery/indefinite-quantity contract by the **U.S. DOD**. This contract provides for the procurement of antenna interface units and communications trays, technical data, assemblies, sub-assemblies and spares for the P-8A Poseidon communications suite in support of the Navy, foreign military sales customers and the Government of Australia. Work will be performed in West Chester, Ohio, and is expected to be completed by October 2028. Pole/Zero, as part of MPG Solutions' flagship brand, analyzes, designs, builds and supports interference mitigation and spectral purification solutions for industrial and defense manufacturers and integrators of RF/microwave electronics.

Northrop Grumman Corp. received funding through the manufacturing and industrial technology division of the **Air Force Research Laboratory** for enhancements to its hypersonics manufacturing technology. The $8.8 million contract supports improvements that will help to shorten production times and drive affordability for hypersonic weapons in production. The company combines traditional manufacturing techniques with innovative manufacturing approaches and digital engineering to reduce part counts, inspection and touch labor. This comprehensive approach ensures the successful transition of hypersonic weapons from research and development to production while enabling sustainable, predictable and affordable life-cycle costs.

CAES, a provider of mission critical electronic solutions, announced it has been awarded a Low Rate Initial Production Phase 2 (LRIP2) contract from **Lockheed Martin Corporation**. Under the contract, CAES will supply its high performing phased array antennas to support Lockheed Martin's Advanced Off-Board Electronic Warfare (AOEW) system. The announcement follows the Low Rate Initial Production Phase 1 (LRIP1) contract that CAES was awarded earlier this year. The AOEW program delivers electronic surveillance and attack capabilities for U.S. Navy Ships. The AOEW system has the ability to work independently or with the ship's onboard electronic surveillance sensor, AN/SLQ-32(V)6 which also features CAES antennas.

Elbit Systems Ltd. announced that its E-LynX™ tactical software-defined radio (SDR) solution was selected by the **Spanish Ministry of Defense (MOD)** Directorate-General for Armament and Material for the "URGENT ACQUISITION OF V/UHF SDR RADIO EQUIPMENT" program. This follows the Spanish MOD's selection of

the E-LynX™ SDR solution for its combat battalions in November 2020 and for its 8×8 Dragon Vehicles in November 2021. The E-LynX™ SDR solution will be manufactured and maintained in Spain as a national sovereign radio, equipped with Spain's national crypto solution, through the cooperation between Telefonica and Elbit Systems.

Comtech has announced that the company was recently awarded a contract to install a 5G virtual mobile location center (vMLC) production site and deliver location-based services for a tier-1 mobile network operator in Canada—further expanding the company's drive to be the world's preferred precise, network-based geolocation services provider. Comtech's vMLC system is used to help pinpoint the location of mobile devices connected to 5G networks. This contract will significantly enhance 9-1-1 rapid response capabilities in a wide variety of emergency situations—allowing the mobile carrier to benefit from a cloud native platform and providing public safety agencies with services to more accurately locate 9-1-1 callers.

PEOPLE

▲ *Eric Higham*

Microwave Journal announced the hire of **Eric Higham** as technical editor. Higham previously worked as director of the advanced semiconductor applications and the advanced defense systems services at Strategy Analytics. He is an industry veteran with more than 40 years of semiconductor experience. Previously, he performed a variety of engineering, business development, marketing and management functions for M/A-COM, MicroDynamics and Raytheon. Higham holds an MSEE degree from Northeastern University and a BSEE degree from Cornell University. He can be reached at ehigham@mwjournal.com.

▲ *Theo Ruas*

Indium Corp. announced that **Theo Ruas** has been promoted to the role of global sales manager, metals and compounds. In his new role, Ruas leads all aspects of global sales for metals and compounds, including gallium tri-chloride, high-purity indium and the reclaim of indium gallium, and tin. He also supports product management with market information for the development of new technologies. Ruas ensures a healthy sales opportunity funnel and progress, engages with the company's largest customers and manages pricing.

▲ *Michael Roberg*

mmTron Inc., a fabless designer of mmWave broadband products for the satcom, 5G/6G, aerospace and defense markets has named **Dr. Michael Roberg** as

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Fig. 1 The R&S CMX500 radio communication tester is ideal for assessing voice service performance.

Testing Voice Services In 5G NR

More and more network operators have started to deploy 5G standalone (SA) networks, opening the door for high quality 5G voice over New Radio. VoNR is the voice service enabler for 5G, using 5G core and IP multimedia subsystems (IMS). The session initiation protocol (SIP) is the base IMS protocol and establishes connections between subscribers. 3GPP introduced and standardized the enhanced voice service (EVS) codec as the new voice codec family for 4G IP based mobile wireless speech services, which is also suitable for 5G systems. Every mobile device must have an IP address provided by the network. The IMS infrastructure establishes the connection between mobile devices and manages the relevant quality of service (QoS) flow for optimized voice experience.

VONR TEST REQUIREMENTS

The general VoLTE and VoNR test setups are very similar, yet different test areas need to be examined. Testing the basic implementation and functional behavior are the starting points and include registration on the IMS server and call setup procedures. Testing voice in 5G also includes VoLTE aspects for the non-standalone (NSA) and EPS fallback scenarios. These provide the handover from NR to LTE, or a RAT fallback during voice connection setups when 5G coverage is limited. Lastly, VoNR audio quality tests are needed to assess voice performance and user experience. A test system for voice over 5G must fulfill complex requirements and support the EVS codec, along with the adaptive multirate (AMR) wideband and narrowband codecs (AMR-WB, AMR-NB).

ALL-ROUNDER TEST SOLUTION FOR MOBILE DEVICES

The R&S CMX500 radio communication tester ***(Fig. 1)*** has everything needed for testing voice services on mobile devices. The solution supports LTE and 5G NR testing for both SA and NSA connectivity. It also features an internal IMS server for registering 5G devices and setting up necessary bearers and QoS flows for voice services. The IMS server comes with a virtual user equipment (UE) emulation for establishing mobile originated and mobile terminated end-to-end voice calls in loopback mode for fast and easy VoNR functional tests. Users can select the supported codecs such as EVS, AMR-WB or AMR-NB and their codec rates. The web-based graphical user interface R&S CMsquares makes controlling the setup and testing EPS fallback scenarios easy.

TESTING AUDIO QUALITY FOR BEST USER EXPERIENCE

To test audio quality during a call, an audio analyzer is required, which must be able to generate and analyze audio waveforms using the latest PESQ® or POLQA® methods. POLQA® is used for audio quality measurements during VoNR and VoLTE calls. In the R&S CMX500 setup, the audio data can either be output via IP or come from the R&S CMX-ZG180A external media endpoint if an analog audio analyzer is preferred ***(Fig. 2)***, giving users maximum flexibility. In electrical measurements of the mobile device under test, the speaker output can be connected directly to the audio analyzer input and the microphone output directly to the audio analyzer. For acoustic tests in line with 3GPP and ETSI, the audio analyzer can use an artificial head with artificial ear and mouth, all available from third-party suppliers.

SMALL FOOTPRINT AND EASY OPERATION

Thanks to a recent upgrade, the R&S CMX500 features a significantly reduced one-box footprint. It offers easier handling combined with debugging and analysis capabilities which enable vendors to rapidly develop and deliver 5G voice services.

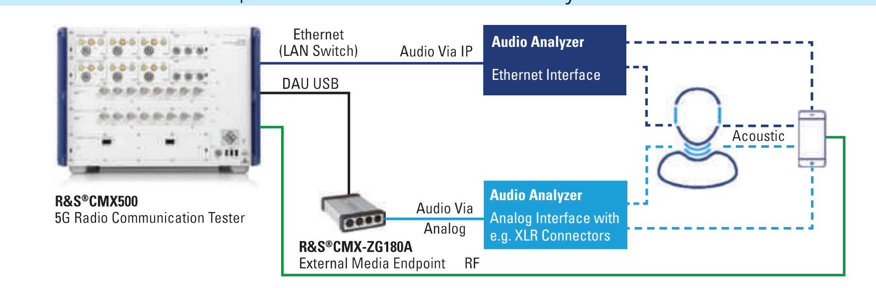

Fig. 2 Flexible test setups for 5G audio quality analysis.

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For in-depth guidance on voice calls in 5G NR, download the full white paper: https://www.rohde-schwarz.com/vonr-wp

Engineering Fellow based at the company's Redwood City headquarters. As a senior technical leader, Roberg has developed innovative aerospace and defense microwave products for amplifier, radar, communication and sensing applications. Most recently, he served as MMIC design engineering fellow for Qorvo Inc. in the high performance analog business unit, where he was responsible for GaN MMIC product development for commercial and military applications.

Wolfspeed, Inc. announced the promotion of **Elif Balkas** to chief technology officer, succeeding the late Dr. John Palmour, a co-founder of Wolfspeed. In her role as vice president of research and development in Wolfspeed's Materials organization, Balkas shaped the company's technical strategy on wide bandgap materials and drove its development execution to maintain Wolfspeed's position as a leader in SiC for Power and RF device applications. She has overseen multiple significant technology milestones during her tenure at the company, including the development of 150 and 200 mm boule growth systems and processes, the dramatic reduction in crystal defect levels that saw higher device yields and advancements in wafer processing. "I'm excited to continue building upon the legacy that John created and unlock new innovations and applications for SC," said Balkas. "It's an exciting time of growth at Wolfspeed and I look forward to the new challenge of finding greater efficiencies as we continue to expand the reach of our technology."

▲ Chae Lee

Tagore Technology Inc., a pioneer of high-power GaN-based RF switches and power management applications, announced the appointment of **Chae Lee** as chief executive officer. Lee brings more than 35 years of experience to Tagore Technology. Prior to joining Tagore, he was president and CEO of Insyte Systems. Before that, Lee was senior vice president and general manager of NXP's Secure Interface and Power Solutions Business Unit where he grew the business unit's revenue to $1B. Prior to NXP, Lee spent 16 years at Maxim Integrated Products where he developed multiple new product lines at Maxim and as senior vice president and general manager of the Mobility Group, grew its revenue from $350M to $1B.

REP APPOINTMENT

Richardson Electronics Ltd. announced a global distribution agreement with **Gallium Semiconductor**. With their headquarters located in Singapore, Gallium Semiconductor is an innovative supplier of RF GaN semiconductor solutions for 5G communication networks as well as aerospace, defense, industrial, scientific and medical applications. The agreement aligns with both companies' commitment to providing high performing, high efficiency RF GaN products.

INVITED PAPER

Surviving the Great Commercial Space Shakeout

Chandra Hackenbruch
Analog Devices

TRANSFORMATION OF THE LEO SATELLITE INDUSTRY

In recent years, the arrival of well-established commercial launch services has brought launch costs down significantly lowering the barrier to entry. This has opened the market to new players and innovators in the low Earth orbit (LEO) satellite industry.

In parallel with reduced launch costs, satellites have decreased from the size of a bus to something you can hold in your hand. The combination of lower launch costs and smaller satellite size is reducing the overall mission cost. Gone are the days of space missions belonging only to space agencies such as NASA and legacy satellite companies.

NON-SPACE INDUSTRY DRIVERS

Commercial space applications are rapidly growing in non-space industries such as energy and mining, agriculture, automotive, telecom, medical and education. Companies in these industries are investing in space to differentiate and expand service offerings to diversify revenues. This "Space-for-Earth" economy industry disruption is driving new use cases, capabilities and users for satellite-based data. There are many examples of the space sector already playing a role in non-space industries. Geospatial satellite technology helps the mining industry by identifying areas for oil exploration and providing imagery of mining sites. Global positioning systems (GPS) satellite technology guides ride-share services such as Uber and Lyft and as the automotive industry moves towards a driverless future, the accuracy of maps becomes a priority. Satellite data helps the agricultural industry make more informed crop development decisions by improving weather forecasts. Satellite technology is changing access to healthcare for remote regions worldwide and satellite data is advancing medical knowledge.

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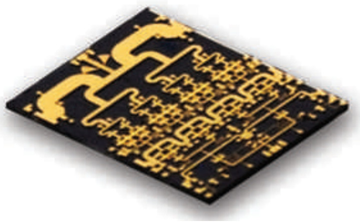

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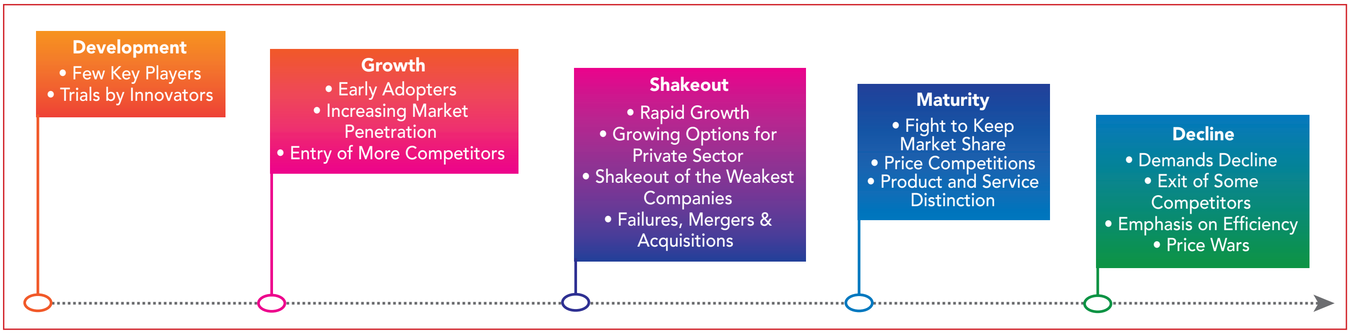

Fig. 1 **Industry lifecycle.**

The private sector is increasingly and actively securing assets in space with these efforts driven by the need for internet access and data. We expect exponential growth of this data-based, Space-for-Earth economy and we expect the emergence of a "Space-for-Space" economy with space-based services and products to support life in space.

NON-SPACE DRIVER EFFECTS

As more companies turn to space for business opportunities that they hope will expand revenue streams and enhance life on Earth, the space industry risks saturation. Satellite manufacturers and launch services will need hardware and software solutions from system equipment, component, test and measurement and software companies to make these new satellite constellations and business models a reality.

INDUSTRY LIFECYCLE

As is the case with many new industries, some companies in the early stages of the LEO satellite boom may not survive and there will be consolidation as this industry matures. Companies that serve this market will need to understand how to adjust and strengthen their business strategy and build infrastructure as the LEO satellite industry evolves through the industry lifecycle. Semiconductor companies with proven maturity in the space market should be aware of where the LEO satellite industry is in this lifecycle. This will help them make wise decisions about partnering with end customers along with developing resilient and sustainable infrastructure.

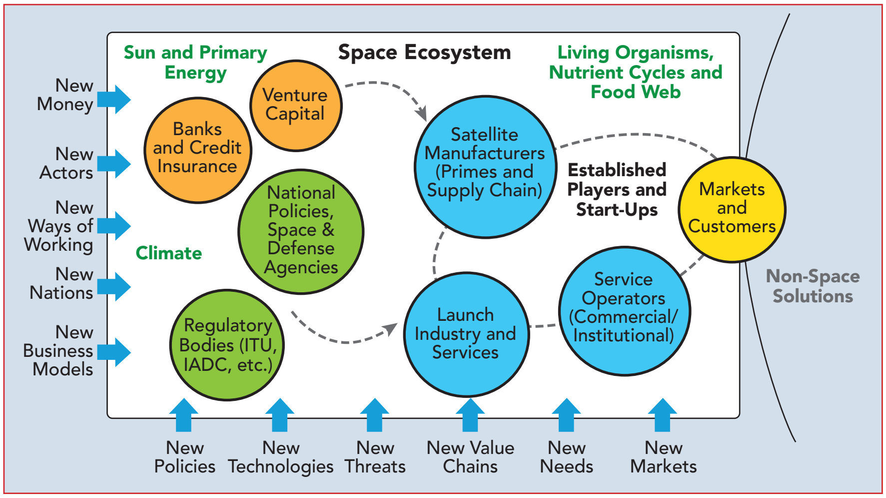

Fig. 2 **Commercial space ecosystem.**

Figure 1 shows the five stages of the satellite industry lifecycle and some characteristics of those phases. Currently, the LEO industry is in a period of rapid growth and evolution and it has entered the Shakeout phase of the lifecycle. In this phase, some companies are naturally eliminated because their business strategies do not keep up with the growth of the market, but some companies can prosper versus their competitors in this phase. At this point in the commercial space industry, non-traditional space investors and influencers are realizing the value of new capabilities arising from the vast amount of high speed data provided by LEO satellites.

WHAT HAPPENS NEXT?

The increase in data traffic enabled by LEO satellites is creating demand from satellite manufacturers, launch services and service providers. These companies are facing rising pressures to reduce launch costs and product development times. They must develop systems and networks that address the increased demand for BIG data, along with the desire for ubiquitous connectivity and reduced propagation delay. To achieve these goals, companies are developing innovative models for data analytics and increasing digitization.

Business-to-business companies that enable these manufacturers and services must adjust to shifting market demands with innovative solutions that support these challenging applications. This is leading to a natural selection process where companies looking to capitalize on emerging space opportunities are starting to choose suppliers with a proven reputation for high-reliability products in commercial space applications. Through proof of resilience, scalability, growth and sustainability, stronger companies will begin to eliminate the weaker competition. Larger, well-established companies in the commercial space ecosystem may choose to strategically acquire companies that are smaller or struggling. This consolidation

phase will affect the entire ecosystem as consumers, service providers, system/sub-system manufacturers and component companies start to define and differentiate their niche in the Space-for-Earth economy. How companies survive the Shakeout phase of Figure 1 will depend on where they fall in the ecosystem of commercial space as noted in ***Figure 2***.

SURVIVING THE SHAKEOUT

Semiconductor companies such as Analog Devices, Inc. (ADI) fall within the "Satellite manufacturers" circle as a supplier. Historically, a large part of Analog Device's business supports the traditional geostationary Earth orbit (GEO) satellite market segment where satellites are larger, more expensive and designed for longer missions. To survive the Shakeout phase in the commercial space industry, companies like ADI must develop business models that enable customers to meet the demands of this new LEO satellite space dynamic (see ***Figure 3***).

The following are descriptions of focus areas that are critical for success in the future:

Mission-Based Product Offering

Performance and reliability are critical attributes of the space industry, but companies must also focus on reducing costs to customers, especially in the high volume LEO market. ADI has expanded their portfolio of space products to include two new grades addressing the wide-ranging needs of the emerging commercial space satellite industry. These new product grades focus on LEO satellites and mega-constellations orbiting in low radiation environments as well as addressing the evolving cost pressures on more traditional GEO satellites. With over five decades of heritage building space-grade components, ADI is focused on developing products that meet levels of flexibility, reliability and quality suitable for any mission profile.

Commercial Space Low (CSL)

This product grade targets cost-constrained or high volume requirements. CSL offers basic testing and screening suitable for LEO constellations orbiting in lower radiation environments.

Commercial Space High (CSH)

This product grade targets applications with the highest level of reliability. With this product grade, customers can take advantage of cost savings and advanced features in comparison to traditional space products. CSH offers the highest screening and radiation qualification level with the most rigorous testing. This product grade can be used where no hermetic package option is available (equivalent to QML V using SAE AS6294 as a guideline). CSH includes everything offered by CSL, plus high-reliability screening and high-reliability quality conformance inspection.

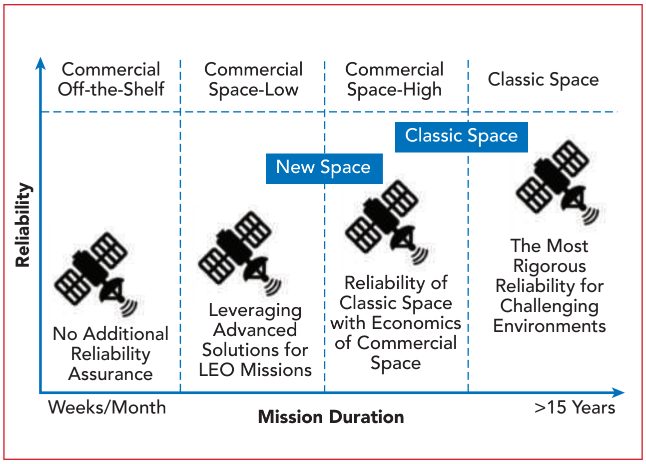

Fig. 3 Space product classification at ADI.

PLATFORMS FOR COMPLEX FUNCTIONALITY

The time to develop new technology and payloads and then launch satellites has dropped from years to months. This shortened development cycle, coupled with an increase in IC functional complexity creates a need for solutions that evaluate parts faster in system applications. Customers do not have time to build evaluation boards and develop code to integrate parts in their system, so supply chain companies are helping customers get their solutions working with minimal time, effort and investment. ADI is addressing this opportunity by releasing turnkey, system-level open platforms. Their beamforming "bits-to-beams" platforms allow customers to start evaluating and confirming beamforming algorithms faster. These efforts enable faster development cycles to support the dynamic growth that the industry is experiencing.

WE ALL WIN

The growth of private sector industries embracing the commercial space market is driving the growth of satellite services. As opportunities expand, the satellite industry is addressing the need for reduced launch costs, smaller satellites, mega-constellations and the reality that satellite-based data demand is rising rapidly. As companies enter this market, business leaders will need to develop business models and strategies to take advantage of the rapid growth while allowing for scalability and sustainability. As with any growing industry, making these decisions can be both challenging and rewarding as companies look to capitalize on market growth. The industry will focus on the challenges of developing more sophisticated, cost-effective products to meet the evolving size, weight and performance requirements of high density LEO constellations, while simultaneously reducing time-to-market. ■

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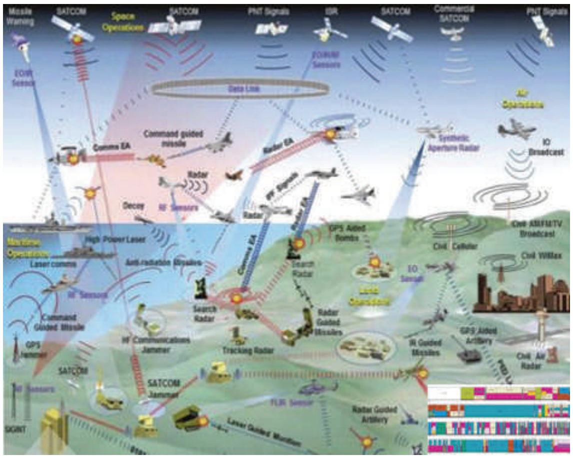

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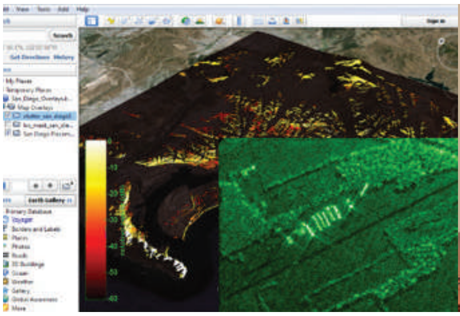

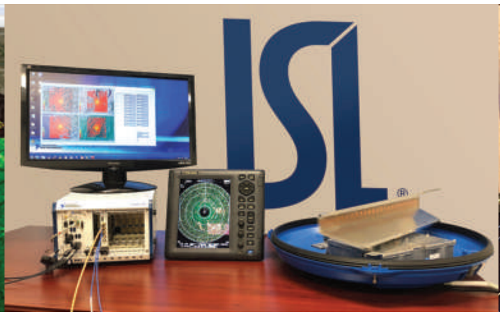

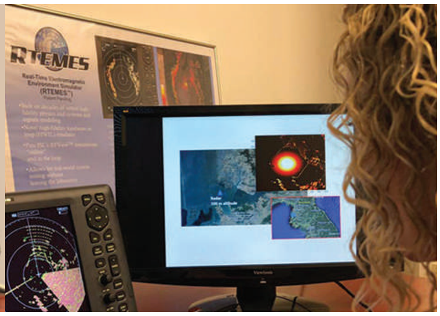

INVITED PAPER

Combining GEO Satellite and Wireless Transports into a Low Latency Internet Service

George Choquette
Senior Vice President, Hughes

In September 2022, Hughes Network Systems, an EchoStar company, launched a new multi-transport consumer offering for U.S. customers that combines the advantages of geostationary (GEO) connectivity with the low latency of a terrestrial wireless transport for a more responsive satellite internet browsing experience. Offered under the HughesNet® brand, the new HughesNet Fusion™ plans leverage innovative enterprise software-defined wide area networking (SD-WAN) techniques to combine the low latency of wireless (specifically LTE) with the high capacity and throughput of GEO satellites into an offering for home and small business users (see ***Figure 1***). Built-in, active optimizing technology balances the responsiveness of LTE and the high capacity and throughput of satellite simultaneously to send data traffic intelligently and transparently over the best transport path.

Named for the fusion of the benefits of LTE and GEO satellite transport, the offering provides excellent performance for video streaming, video conferencing, web browsing, social media, banking and home office applications. It offers a satisfac-

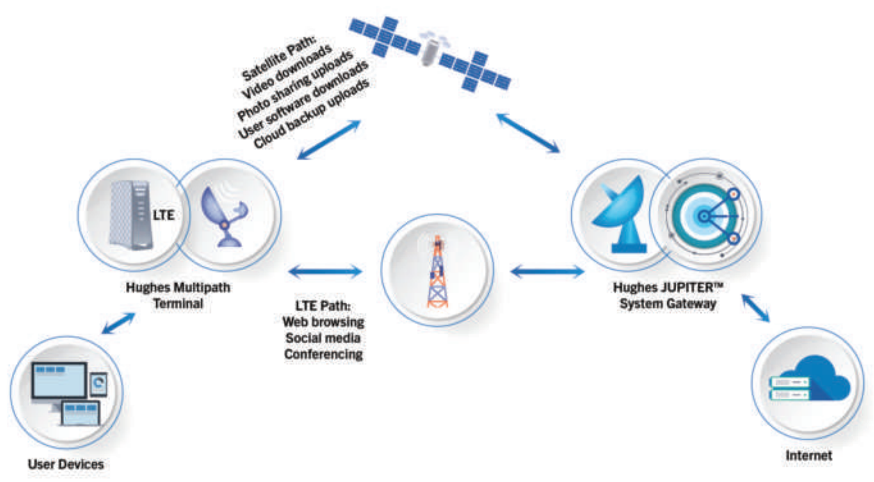

Fig. 1 The HughesNet Fusion network.


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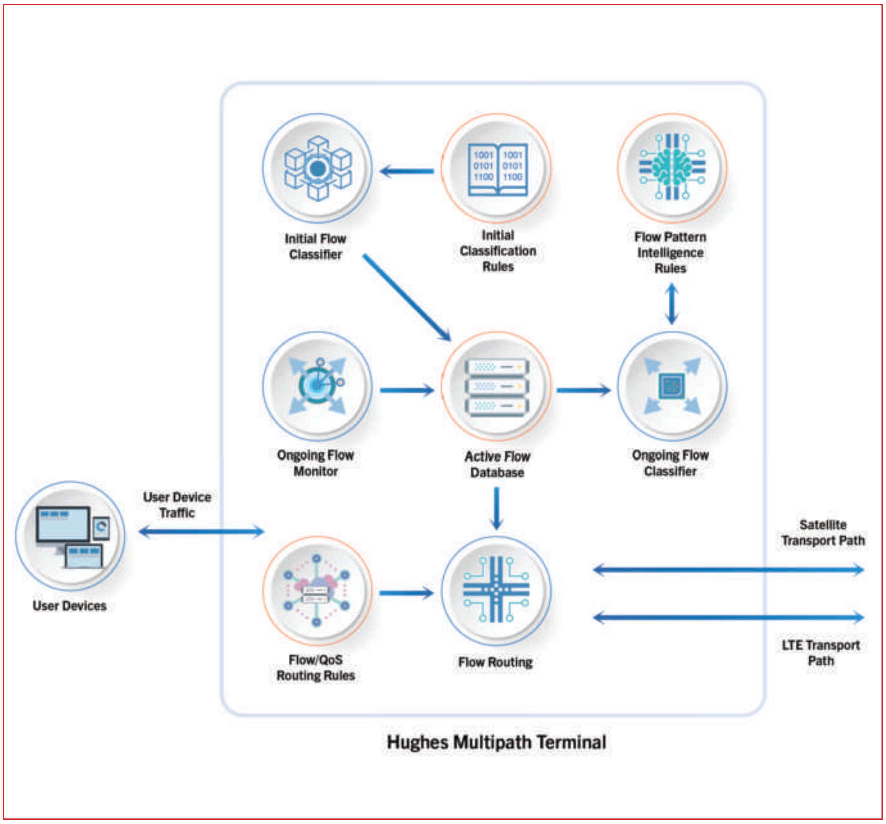

▲ Fig. 2 The ActiveTechnologies software flow.

tory real-time gaming experience, which has been a challenge for GEO services. However, gaming applications notoriously consume gigabits of data, which makes them costly to run on any satellite-based service.

The LTE path offers lower latency and better response time for interactive internet applications than both GEO satellites and low Earth orbit (LEO) satellites. While wireless transport can be expensive when used to stream high-definition video, satellite transport is more cost-effective than fixed LTE, especially for users who watch a lot of video. However, satellite incurs higher latency, as data must travel up to a satellite orbiting approximately 37,000 kilometers away and come back down, introducing a noticeable delay in some applications. The new hybrid offering uses both LTE and satellite transports simultaneously on an application and flow-aware, packet-by-packet basis to get the best of each method without the relative cost or latency drawbacks. A HughesNet Fusion service plan includes a volume of LTE service as a cost-effective complement to the GEO satellite service. This specific transport is transparent to the end user, is compatible with smartphones, TVs and computers and preserves the privacy of user traffic.

INTELLIGENT INTERNET TRAFFIC MANAGEMENT

The Hughes ActiveTechnologies™ software forms the core of the Fusion plan (see ***Figure 2***). This proprietary and intelligent software classifies data traffic based on quality of service (QoS) requirements and routes each type of data over the optimal transport path. The software recognizes when the QoS requirements for an active traffic flow change and automatically changes the routing when appropriate.

To make the transition from HughesNet to HughesNet Fusion plans simple for end users, Hughes built ActiveTechnologies software, the LTE device and the wireless antenna into a new self-contained multipath terminal designated as the Hughes WL3000 terminal. Hughes also built its ActiveTechnologies software into multipath gateways connected to internet


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points-of-presence, as illustrated in ***Figure 3***. Turning on the Fusion offering is as simple as plugging in the new terminal and connecting it to the LAN port in the standard HughesNet router; no parameter entry or expertise is required. The new terminal works seamlessly with the existing router's Wi-Fi access point to serve all the smartphones, computers, smart televisions and other devices within the home. User device traffic travels seamlessly over Wi-Fi into the satellite router and is relayed to the multipath terminal. In the terminal, the ActiveTechnologies software forwards the traffic to the LTE modem or back to the satellite router for transport.

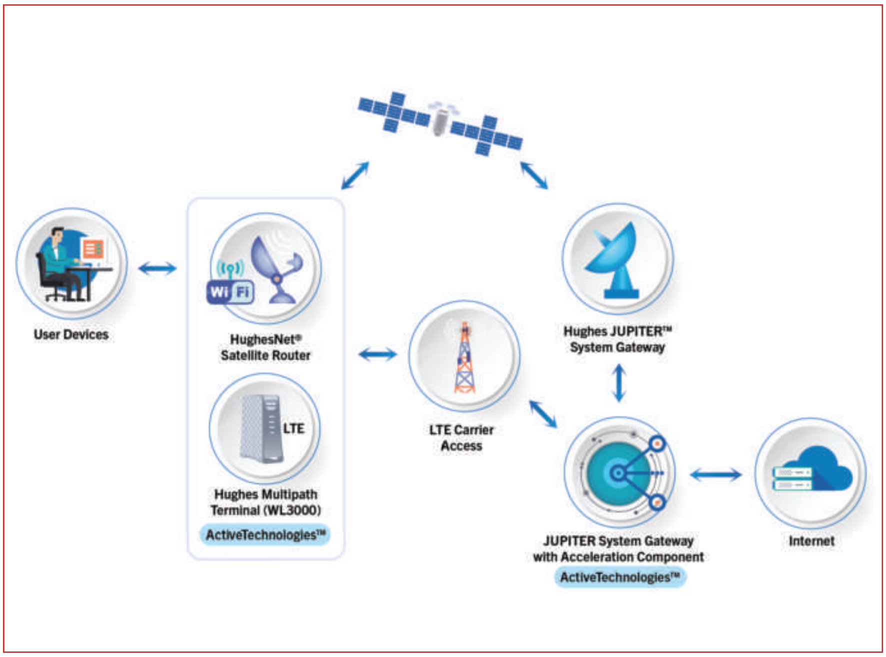

Fig. 3 The HughesNet Fusion network with ActiveTechnologies software.

AUTOMATIC TRAFFIC CLASSIFICATION AND OPTIMIZED ROUTING

When a customer accesses the internet using the HughesNet Fusion plan, the traffic classifier function examines the traffic flow to make an initial determination based on the values of fields in packet headers, if available. However, many internet applications like video streaming, web browsing and banking are conveyed using the hypertext transfer protocol (HTTP) and cannot be distinguished by examining packet header fields. As the flow of traffic proceeds, the classifier monitors a set of criteria, such as packet rates and sizes, to determine if a QoS change is indicated.

As an example, video streaming starts with low latency protocol handshakes, security exchanges and a few packets to request the desired video from the internet host, then transitions into a high-throughput video stream download where transport latency is not perceptible by the user. The ActiveTechnologies software classifier detects that change in the traffic pattern and adjusts the flow classification to video streaming so that the appropriate packets in the flow are directed to the satellite path. The use of traffic patterns, rather than traffic content, enables the classification of encrypted flows without compromising user security and privacy. This constant traffic pattern monitoring and reassessment continues for the duration of a traffic flow, accommodating those applications that reuse the same protocol connection to an internet host server for different traffic types. The detection and monitoring function is also useful when an established connection changes during operation. An example of this scenario is when traffic flow changes from fast bidirectional exchanges to extended one-way download or upload. The routing function directs

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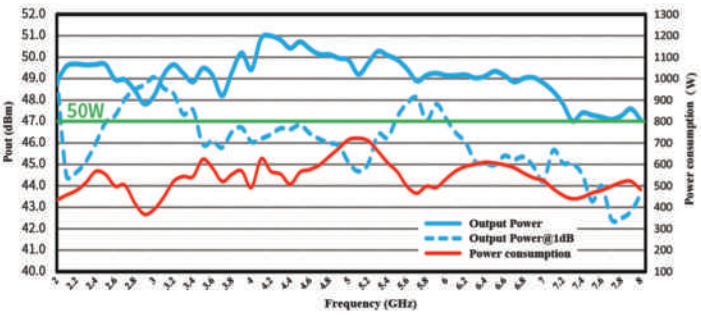

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the packets of a given flow to the transport path designated for the classified QoS, routing to either LTE or satellite. This routing is performed independently for traffic in both directions between the user device and the internet host.

Web browsing provides another interesting example of how the HughesNet Fusion offering improves user experience. A typical web page contains dozens to hundreds of objects, like text, GIFs, ads and video clips, that are served by many different internet hosts. Regardless of transport method, the web browser on the end user device requests separate connections to each internet host and sometimes multiple connections to the same host. With HughesNet Fusion, ActiveTechnologies classifies each connection separately, assesses the QoS requirement continuously and routes the data accordingly. Objects such as text and GIFs can travel over LTE, while embedded video clips can transmit over satellite. This optimizes performance and cost, serving the web page over both transport methods and providing a seamless experience to the end user.

ADAPTING ROUTING TO TRANSPORT PATH CONDITIONS AND CAPACITIES

HughesNet Fusion service plans also use ActiveTechnologies to optimize service availability automatically. By constantly monitoring each transport path, the software automatically adjusts traffic for network availability; if one path becomes momentarily unavailable, the system sends traffic flows over the other path. In this scenario, the software prioritizes availability over performance and cost to ensure users can still use the internet for business or entertainment. As soon as the ActiveTechnologies software determines that both transport paths are again available, the system reverts to traffic routing patterns that optimize service performance and cost. The software also adapts traffic routing to conserve the low latency transport for use throughout the month. This adaptation is automatic and gradual, resulting in no disruption to the service user. With the potential for multiple routing adjustments over the course of the month, users reap the maximum benefit of their low latency LTE transport.

RULES OF THE ROAD FOR TRAFFIC CLASSIFICATION

Hughes engineers pre-set the performance, cost and availability parameters that guide the ActiveTechnologies software. The parameter values can be configured from the operations center, enabling real-time tuning of the performance and efficiency of the active service and allowing tailoring of operation for different service plans or transport characteristics. Configuration rules determine how traffic flows are classified for QoS requirements based on initial packet header values and monitored traffic characteristics including packet size, rate and volume. Additional configuration rules determine how transport paths are assessed for real-time characteristics including availability, throughput, latency and packet loss rate. This suite of controls enables ActiveTechnologies to maintain service availability and optimize quality automatically in the presence of changing performance of the underlying transport networks.

A NEW MULTI-PATH FORWARD FOR SATELLITE INTERNET

HughesNet Fusion plans meet the needs of rural consumers who live beyond the reach of wireline services, yet within the footprint of wireless networks. In these cases, the wireless service may not be strong enough for single-path service but it is likely sufficient to augment GEO satellite service. This offering leverages the capacity density, rural availability and high-throughput of GEO satellite connectivity along with the low latency of wireless transport to deliver low latency satellite internet. HughesNet Fusion represents the latest of a series of satellite internet innovations from Hughes, the company that innovated the first satellite internet access system, the first high-throughput spot beam satellite


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Fig. 4 The HughesNet Fusion WL3000 modem/router.

Fig. 5 The HughesNet Fusion indoor antenna assembly.

for internet access and the first applications of DVBS2 and DVBS2X standards for satellite internet service. Each of these innovations has enhanced HughesNet service, the satellite internet service on which millions of people depend, while enabling the Hughes JUPITER™ System ground platform that the company sells to other operators around the world.

In September 2022, Hughes introduced HughesNet Fusion to customers in the southeast region of the U.S. Soon after, the company made the offering available to new customers in that region and then quickly expanded the service nationwide. The WL3000 modem/router for this service is shown in ***Figure 4***, while the indoor wireless antenna assembly is shown in ***Figure 5***. ■


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INVITED PAPER

The Future of UWB: Reconciling Sensing with Low Energy Consumption and High Bitrates

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Among a growing number of wireless communications options like Wi-Fi, Bluetooth and NFC, an increasing number of applications are using ultra-wideband (UWB) technology's secure and fine-ranging capabilities to do their magic. This magic is enabling many applications. Hands-free entry solutions leverage UWB's ability to track approaching people and the technology can be used to automatically unlock doors in a car or a building. Asset tracking and location-based services harness the power of UWB, especially at indoor locations where it is hard to acquire or maintain a stable GPS signal. Use cases include locating assets in warehouses, hospitals or factories with centimeter accuracy and helping people navigate large spaces such as airports and shopping malls.

Acknowledging the technology's growth potential, market research firm Data Bridge expects UWB's global market value to increase from $1.16 billion in 2021 to $1.84 billion by 2029.[1] This trend is confirmed by ABI Research, which sees annual device shipments of UWB technology in applications like smartphones, vehicles and IoT devices reaching 1.5 billion by 2026, up from 500 million in 2022.[2] It is an evolution that goes hand in hand with the proliferation of new UWB applications that combine the need for sensing with low energy consumption, high interference resilience and high bitrates.

IEEE 802.15.4Z AND STRONG INDUSTRY SUPPORT PROPELS UWB INTO THE MAINSTREAM

Today's impulse radio (IR) UWB systems vastly outperform narrowband radios in terms of ranging accuracy. Enhancements to the UWB physical layer as part of the adoption of the IEEE 802.15.4z amendment in August 2020 have been instrumental in enabling the technology's secure-ranging capabilities. Industrial ecosystems like the fine-ranging (FiRa) and car connectivity (CCC) consortiums have standardized UWB-enabled use cases across the automotive, smart industry, smart home and smart building markets.

While UWB systems have clear technical advantages and their adoption is growing, these systems do present challenges. UWB uses more expensive circuits and systems are more complex. The wideband performance of the systems also results in higher power dissipation than narrowband technologies such as Bluetooth. These challenges jeopardize the long-term operation of battery-powered UWB applications and have

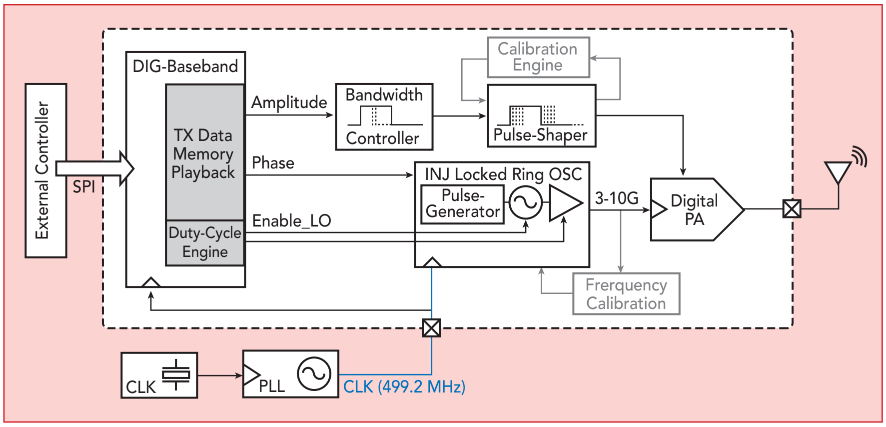


Fig. 1 An IR-UWB IEEE 802.15.4z-compatible coherent asynchronous polar transmitter.

impeded broader adoption of the technology.

A BREAKTHROUGH: A SUB-5 MW, IEEE 802.15.4Z ULTRA-WIDEBAND TRANSMITTER CHIP

In response to the power dissipation challenge, imec introduced a sub-5 mW, IEEE 802.15.4z wideband transmitter chip at the 2021 ISSCC conference. This transmitter chip featured a power budget 10x lower than the UWB state-of-the-art at that time. Fabricated in 28 nm CMOS, with an occupied core area of only 0.15 mm^2, the chip was built to support cost-effective, small form factor UWB deployments. It comes with a power consumption of 4.9 mW in standard-compliant operation while adhering to UWB's stringent spectral emission regulations.

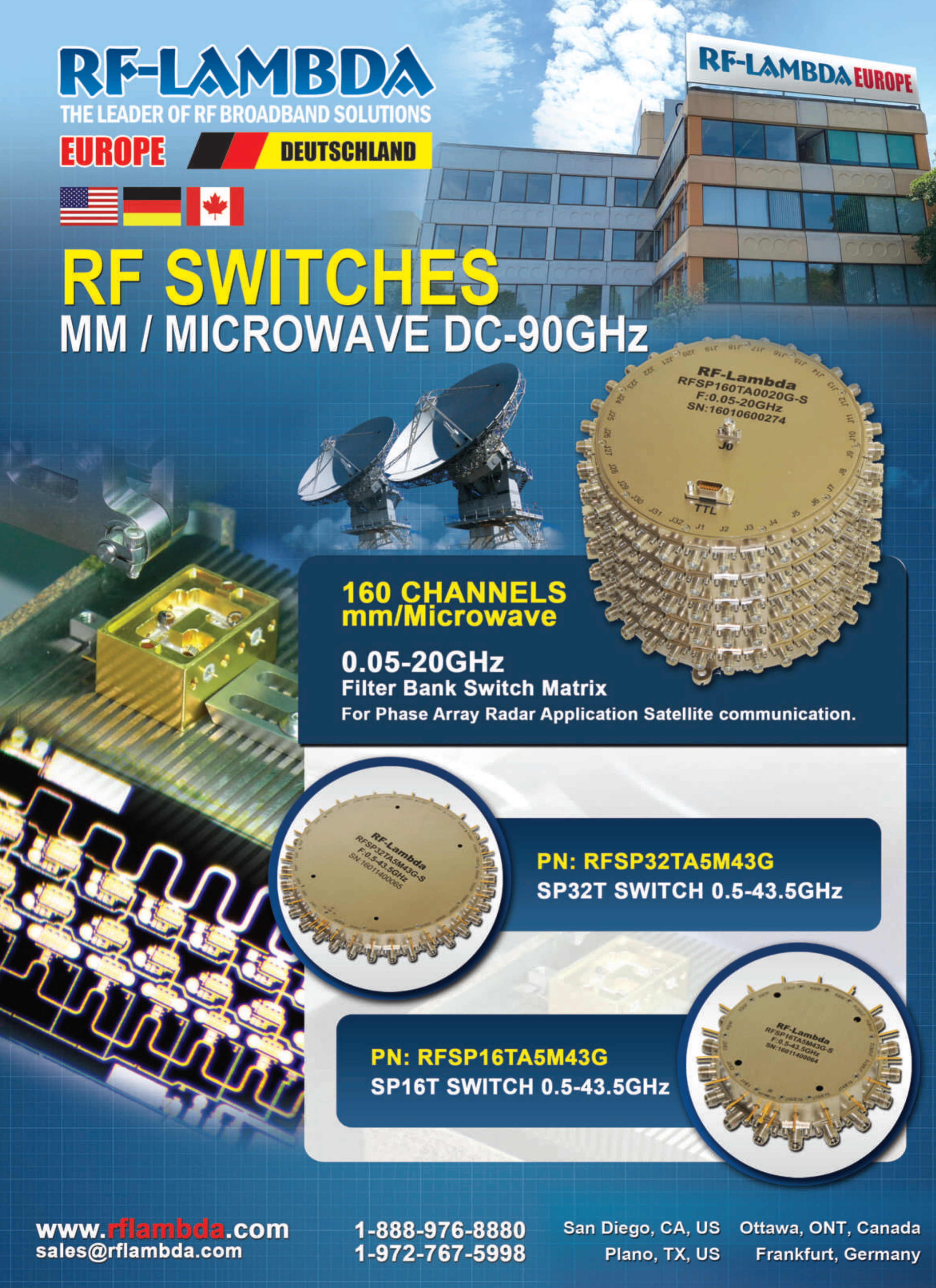
The chip leverages the digital polar transmitter architecture shown in ***Figure 1*** to reduce the IC's power consumption significantly. This architecture differs from conventional IR-UWB transmitters that typically use an IQ mixer to up-convert the output of a baseband pulse-shaping filter to an RF frequency, which is then amplified by a linear power amplifier (PA) before transmission. This traditional approach results in higher power dissipation and this limits battery lifetime, restricting the IR-UWB applications.

A polar transmitter can employ a non-linear PA with higher efficiency. However, the Cartesian to polar transformation results in bandwidth expansion, which can lead to a digital PA (DPA) clock rate that may be four to 10x higher than the chip rate. This results in high power dissipation for the overall system.

In a contribution to the *IEEE Journal of Solid-State Circuits*, imec proposed an asynchronous polar transmitter employing a pulse-shaper that consists of a finite-impulse response (FIR) filter employing current-starved inverter-based delay taps resulting in a good power/performance trade-off.[3] Additionally, injection-locked ring oscillator (ILRO) technology achieves even greater power savings by enabling fast-duty cycling between the IR-UWB transmitter's signal bursts within a packet. This allows sections of the transmitter to be turned off between pulses. The proposed transmitter is compatible with the IEEE 802.15.4z standard, supporting coherent operation while lowering the standard for power dissipation. The IR-UWB transmitter chip also complies with stringent spectrum regulations that dictate the frequencies the UWB transmitter can emit to avoid interference with other wireless services. The chip's asynchronous pulse-shaping design meets worldwide spectral emission regulations while allowing the transmitter to operate close to the maximum power spectral density (PSD).

AN IR-UWB 802.15.4Z TRANSCEIVER TO SUPPORT THE NEXT GENERATION OF UWB APPLICATIONS

Supporting the growing adoption of UWB requires more than a low-power transmitter. The industry requires an optimized UWB transceiver that includes high performance ranging, direction-finding and localization algorithms. Re-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searchers at imec have addressed these issues in a paper at ESSCIRC 2022.[4] In this paper, researchers presented a very low-power IR-UWB 802.15.4z transceiver that strikes a balance between cost-efficient silicon layout, low energy consumption and accurate localization measurements.

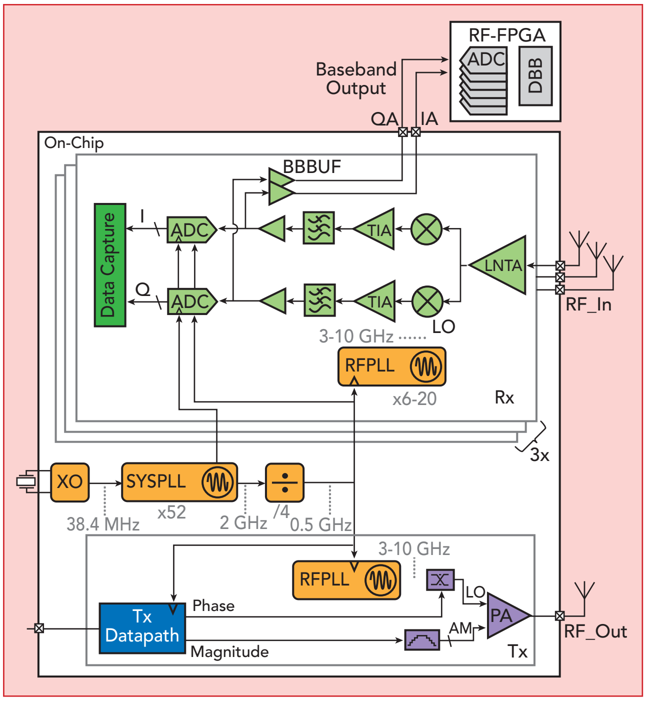

Fig. 2 A 3 to 10 GHz IR-UWB 802.15.4a/z 1T3R transceiver.

The proposed design is implemented in 28 nm CMOS occupying an area of 1.06 mm^2. The chip's reduced power consumption results from a highly optimized, low-power and interference-resilient receiver (Rx) architecture coupled with an innovative digital polar transmitter architecture. A distributed, two-stage digital PLL allows for further reduction of the chip's power consumption and contributes to a reduced measurement time of localization.

The transceiver's system architecture is shown in ***Figure 2***. It contains a system clock generator, along with an energy-efficient polar transmitter (Tx) and three Rxs with self-contained PLLs. The Rx consists of a two-stage low noise transconductance amplifier, passive mixer, TIA (transimpedance amplifier), lowpass filter and analog-digital converter (ADC). All amplifiers in the Rx consist of unit inverter-based gm cells regulated by a self-biased current regulator. The ADC is a 2 GSps 6-bit 2x time-interleaved (TI) ADC, which is a trade-off between TI complexity and slice sample rate. The transceiver consumes 8.9 mW in Tx mode and 21.5 mW per channel in Rx mode while achieving -33 dBm out-of-band (OOB) blocker tolerance.

UWB'S NEXT BIG THING?

While ultra-wideband technology continues to be refined, the industry is exploring the viability of several new UWB applications beyond the typical secure and fine-ranging applications being pursued by the FiRa and CCC consortiums. The technology's large bandwidth makes it possible to build UWB radar systems that extract information in much greater resolution and detail than narrowband technologies. With the short RF pulse properties, the technology could be useful in presence detection systems and it could detect breathing patterns or a person's heartbeat. There are ongoing efforts to create cost-effective UWB radar-on-chip systems that are highly energy-efficient and the size of a fingernail.

This technology could become an enabler in automotive applications. High-end vehicles already contain UWB anchors for secure keyless entry. Instead of adding additional mmWave radar sensors, vehicle manufacturers are exploring the possibility of leveraging the installed UWB sensors for passive presence detection applications. Some of these applications include detecting whether a child or a pet is left unattended in a car or monitoring a driver's physical parameters. In addition to saving on component and installation costs, the power consumption of UWB radar sensors is significantly lower due to their lower carrier frequencies. Auto

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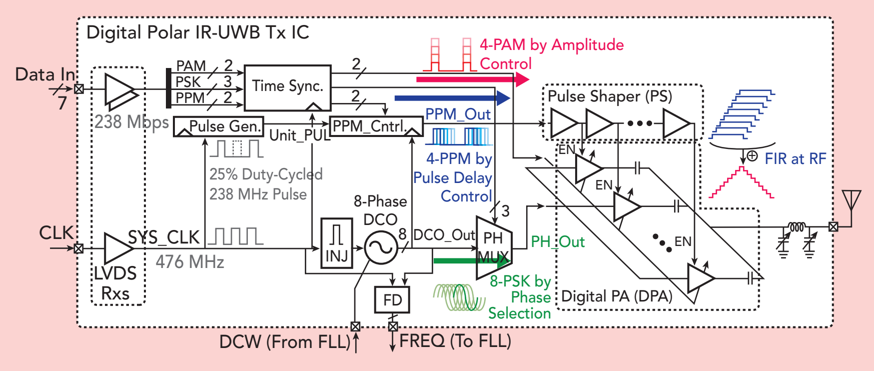

Fig. 3 An energy-efficient high-data-rate IR-UWB transmitter.

manufacturers are actively investigating equipping their vehicles with child detection systems. From the 2023 model year, only vehicles with this feature will be able to get the highest Euro NCAP (New Car Assessment Programme) safety rating.

INCREASING THE DATA RATES OF UWB TECHNOLOGY

Increasing the battery life in UWB applications is an important enabler for the future adoption of the technology. There is a significant development effort in this area, but pushing the boundaries of UWB extends beyond the challenge of energy consumption. Researchers at imec are investigating how the technology can also support very high bitrate applications while maintaining low-power consumption.

Fabricated in 28 nm CMOS and occupying a surface area of 0.155 mm^2, the chip shown in ***Figure 3*** accommodates data transfer rates up to 1.66 Gb/s for in-body and short-range applications. This is more than 50x faster than what is possible using the current IEEE 802.15.4z standard. Despite these record-setting bitrates, the transmitter has a power consumption of less than 10 mW. We believe that the 5.8 pJ/b energy efficiency is at least an order of magnitude improvement over Wi-Fi.

The chip uses sophisticated modulation schemes that build on all-digital phase-locked loops (ADPLLs) and digitally-controlled power amplifiers to achieve the reported data transfer rates. The architecture uses an energy-efficient, low jitter ring oscillator in combination with a low-power polar transmitter to enable those hybrid impulse modulation schemes in the smallest possible footprint. ***Figure 3***, originally published in *IEEE's Journal of Solid-State Circuits*, shows the proposed low-power polar-based IR-UWB Tx capable of performing 3D hybrid impulse modulation for supporting higher data rates. The amplitude and the phase modulation can be performed independently by the polar architecture. Unlike previously presented carrier-less topologies, the proposed Tx modulates the pulse delay independently from the carrier phase.

The impulse waveform is shaped by the digitally-controlled PA (DPA) and a pulse-shaper (PS) that uses eight delay cells to perform FIR filtering in the RF domain. The output of each delay cell enables eight PA cells. The shape and the width of the impulse can be adjusted by the delay of the PS output. An injection-locked ring-based digitally-controlled oscillator (DCO) is adopted to provide low jitter signals for the eight phases of the 8-PSK modulation scheme over a wide frequency range. A 7-bit, 238 Msym/s digital data stream is distributed to PAM, PSK and PPM modulation paths after being synchronized with a 476 MHz system clock (SYS_CLK). The digital PA with 32-unit cells supports up to 4-PAM. The 8-PSK modulation results by selecting one of eight phases from the ILRO using a phase selector (PHMUX).

An application for the architecture shown in Figure 3 is the next generation of smart glasses to enable immersive augmented reality (AR) and virtual reality (VR) experiences. Neuroscientific research could also benefit from high bitrate and miniaturized wireless telemetry

modules for intracortical sensing purposes. In each of these cases, UWB could become a strong competing technology to Wi-Fi since Wi-Fi implementations typically involve more complex systems with larger footprints.

CONCLUSION: UWB IS READY TO SUPPORT MASS-MARKET DEPLOYMENTS

While further research and standardization efforts are required to bring UWB technology to maturity, the promising outcome of initial results proves that UWB can support a wide range of new applications that combine the need for high data transfer rates at short distances, very low energy consumption and a small form factor. UWB technology has proven its ability to support mass-market secure-ranging and localization deployments and this is an important takeaway for commercial companies looking at the potential of UWB. The standardization effort that is currently ongoing within the IEEE as well as the supporting regulatory, interoperability and certification discussions will largely determine the future course of UWB technology.

It is exactly at the crossroads of these two efforts that imec operates. imec works with industrial partners to commercialize the technological breakthroughs achieved by our research teams. They are also active participants in standardization bodies and industry consortiums such as IEEE, CCC and ETSI/FCC to help shape current and future UWB applications. ■

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A Wideband Microstrip Patch Antenna with Dual Polarization

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A wideband microstrip patch antenna having a hexagonal radiating patch with linear and circular polarization is proposed for multiband applications. The radiating patch is perturbed with three slits and is shorted to ground using a copper pin. The perturbation of the radiating patch with three optimum slits enhances the impedance bandwidth. Shorting of the patch to the ground plane changes a portion of the radiated frequency band from linear to circular polarization. The unique feature of the antenna is that it exhibits both linearly polarized and circularly polarized properties in a single structure. It can be used for transmission and reception of differently polarized signals simultaneously. The probe-fed antenna has an impedance bandwidth of 1.29 GHz, 42.4 percent, from 2.4 to 3.69 GHz for $|S_{11}| \leq -10$ dB. It has a broadside radiation pattern with a gain of 3.7 dBi at 2.5 GHz and 5.9 dBi at 3.68 GHz.

The antenna is the heart of all wireless communication equipment and plays an important role in determining the quality of radio communication. Present and future advanced wireless communication systems require antennas to have wide bandwidths to support higher data rates and capable of operating over the multiple frequency bands defined by various protocols. More than one antenna is often required to support different frequency bands and polarizations, leading to an increase in the space required for the antenna, while the available space keeps decreasing.

A conventional microstrip patch antenna transmits linearly polarized radiation over a relatively narrow band. Many advanced wireless communication systems, however, require wide bandwidths to support high speed data communication and multiple application bands. If a microstrip patch antenna is to be used in these applications, it must be modified to provide the wide bandwidths required, as well as having the ability to radiate circularly polarized waveforms.

Much has been reported on bandwidth enhancement techniques, including: 1) slotting or slitting of the radiating patch,[1-4] 2) thicker substrates with a low dielectric constant,[5] 3) stacking of patches,[6] 4) addition of parasitic patches with a main radiating patch,[7] 5) aperture coupling[8-10] and 6) proximity couple feeding.[11-14]

An antenna radiates a signal with circular polarization when it generates two orthogonal modes with the same amplitude and 90-degree phase difference between them. Some of the techniques which have been used to enhance bandwidth can also be used to change the polarization of the antenna, such as perturbation of the radiating patch with slits or slots,[15-17] attaching a stub[18] and stacking of patches.[19] Other techniques include perturbing the patch with spur lines[20] and overlapping patches.[21]

The antenna described here is a wideband microstrip patch antenna that works as a linearly polarized antenna for some portion of the resonant band and a circularly polarized antenna for another portion of the band. The radiating patch is hexagonal with three slits. The patch is shorted to the ground plane using a copper pin, which causes some portion of the linearly polarized band to be converted to circular polarization. The low profile antenna exhibits an impedance bandwidth of 1.29 GHz (42.4 percent), which spans multiple application bands.

ANTENNA DESIGN

The complete size of the antenna is 47 × 40 × 6 mm^3 (see ***Figure 1***). The patch is perturbed with three slits, and the patch and ground plane are shorted using a copper pin with a 0.63 mm radius and 6 mm

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height. The radiating patch is a thin copper sheet on 6 mm FR4 material with ε_r = 4.4 and tanδ = 0.02. A 50 Ω coaxial probe with an SMA connector situated 15 mm from the left edge and 19 mm from the bottom edge of the substrate is used to excite the antenna.

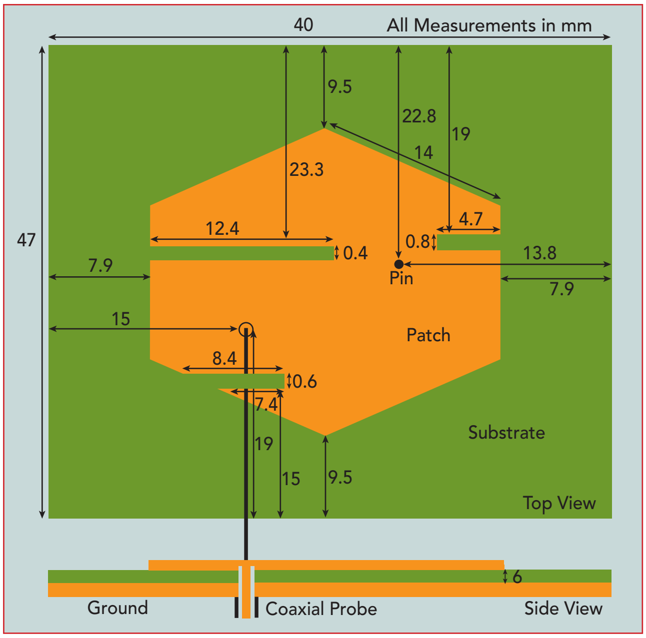


Fig. 1 Top and cross-section views of the antenna design. Dimensions in mm.

Initial Design and Parametric Study

In a microstrip patch antenna, size determines its primary resonant frequency. There is close similarity between hexagonal and circular patch antennas; therefore, Equation 1, which is used for calculating the resonant frequency of a circular patch antenna, and Equations (2) and (3) are used to calculate the primary resonant frequency of the hexagonal patch antenna.[22]

$$f_r = \frac{X_{mn}}{2\pi a_e \sqrt{\varepsilon_r}} c \quad (1)$$

$$a_e = a\left\{1 - \frac{2h}{\pi a_e \varepsilon_r}\left(\ln\frac{\pi a}{2h} + 1.7726\right)\right\}^{\frac{1}{2}} \quad (2)$$

where f_r is the resonant frequency of the circular patch antenna, X_{mn} = 1.8411 for the dominant TM_{11} mode, c is the speed of light in free space, ε_r is the relative permittivity of the substrate and a_e is the effective radius of the circular patch.

$$\pi a_e^2 = \frac{3\sqrt{3}}{2} s^2 \quad (3)$$

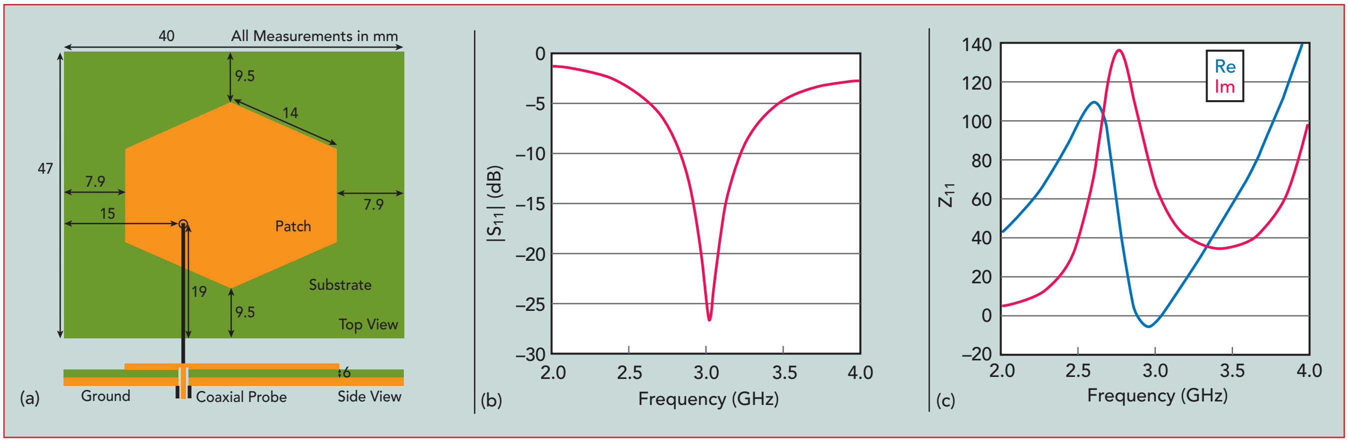
where s is the side length of the regular hexagonal patch.

After parametric calculation with different side lengths, 14 mm was chosen to provide a primary resonant frequency of 3.11 GHz, close to the desired result. After theoretically calculating the resonant frequency of the hexagonal microstrip patch antenna, HFSS version 13 software was used for the initial design and analysis. The optimum probe location was found by placing the probe at different positions on the patch and analyzing the results. At the optimum probe location, 15 mm from the left edge and 19 mm from the bottom edge of the substrate, the primary resonant bandwidth is 390 MHz (2.83 to 3.22 GHz) for $|S_{11}| \leq$ -10 dB (see ***Figure 2***).

Effect of First and Second Slits

Perturbation of the radiating patch with slits adds capacitive reactance and lengthens the surface current path. This added capacitive reactance causes an LC resonance with the stray patch inductance creating an additional resonant frequency band. When the additional resonant band is close to the primary resonant band, the overall bandwidth of the antenna is increased. The lengthening of the surface current path causes a shift of the frequency band toward the lower side of the frequency range.[23-27]

The first slit was initially chosen to be 1 mm wide and 5 mm long. Analysis showed little shift of the resonant frequency toward the lower side of the frequency range and improvement in S_{11}. A parametric simulation using HFSS was done with a 0.4 mm width and various slit lengths. Observing $|S_{11}|$ and the in-



▲ Fig. 2 Initial design: optimum probe position (a), simulated $|S_{11}|$ (b) and simulated Z_{11} (c).

TABLE 1

RESONANT BAND VS. LENGTH OF FIRST SLIT

First Slit Length (mm)	Resonant Band (GHz)	Minimum $\|S_{11}\|$ (dB)
5	2.82 to 3.21	-23.0
6	2.81 to 3.2	-21.5
7	2.8 to 3.2	-20.0
8	2.79 to 3.2	-18.6
9	2.75 to 3.19	-17.3
10	2.68 to 3.18	-16.5
11	2.59 to 3.16	-16.4
12	2.5 to 3.12	-18.5
12.4	2.47 to 3.1	-21.7

TABLE 2

RESONANT BAND VS. LENGTH OF SECOND SLIT

Second Slit Length (mm)	Resonant Band (GHz)	Minimum $\|S_{11}\|$ (dB)
5	2.48 to 3.11	-20.4
6	2.48 to 3.12	-19.6
7	2.46 to 3.12	-17.6
8	2.46 to 3.15	-16.2
8.4	2.46 to 3.18	-16.0

put impedances, a 0.4 mm width and 12.4 mm length provide the best performance; changing the length and width beyond these dimensions provides unwanted results (see ***Figure 3*** and ***Table 1***).

To further improve bandwidth, the hexagonal patch was perturbed with a second slit, keeping the probe position and first slit unchanged. The same optimization process was used. After perturbation with the optimized second slit, the antenna bandwidth was further improved (see ***Figure 4*** and ***Table 2***).

Effect of the Shorting Pin

Shorting of the patch to ground enhances the impedance matching and also introduces a polarization change. The shorting pin acts as an inductance parallel to the resonant LC circuit. When the shorting pin shifts from the center toward the right edge of the patch, the value of the inductance—in series with the static capaci-

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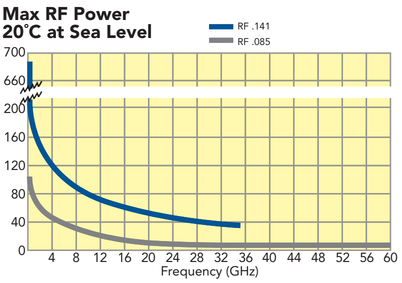

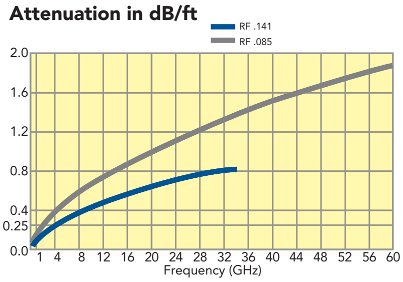

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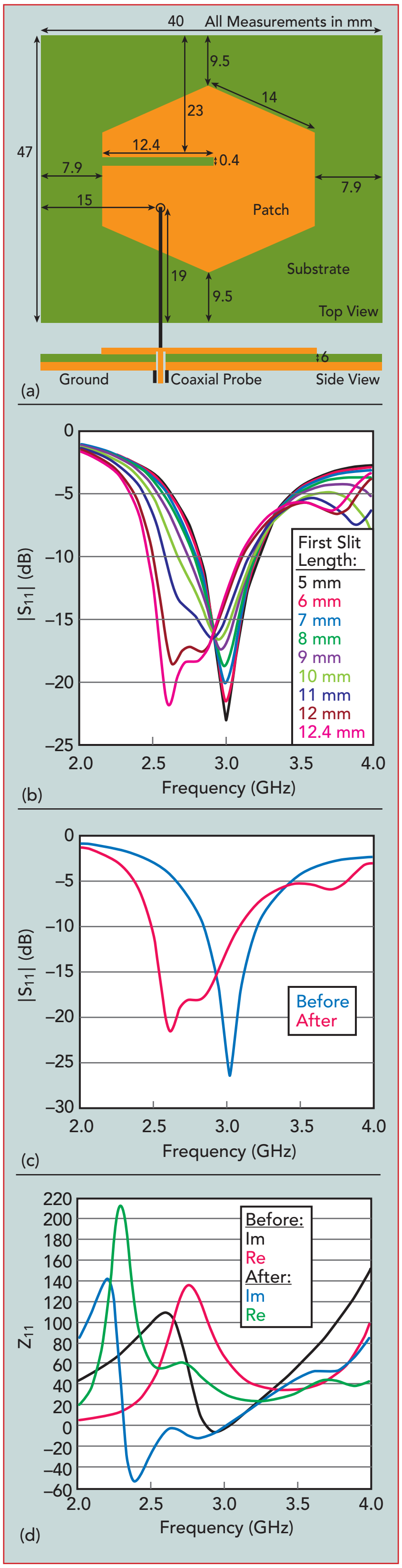
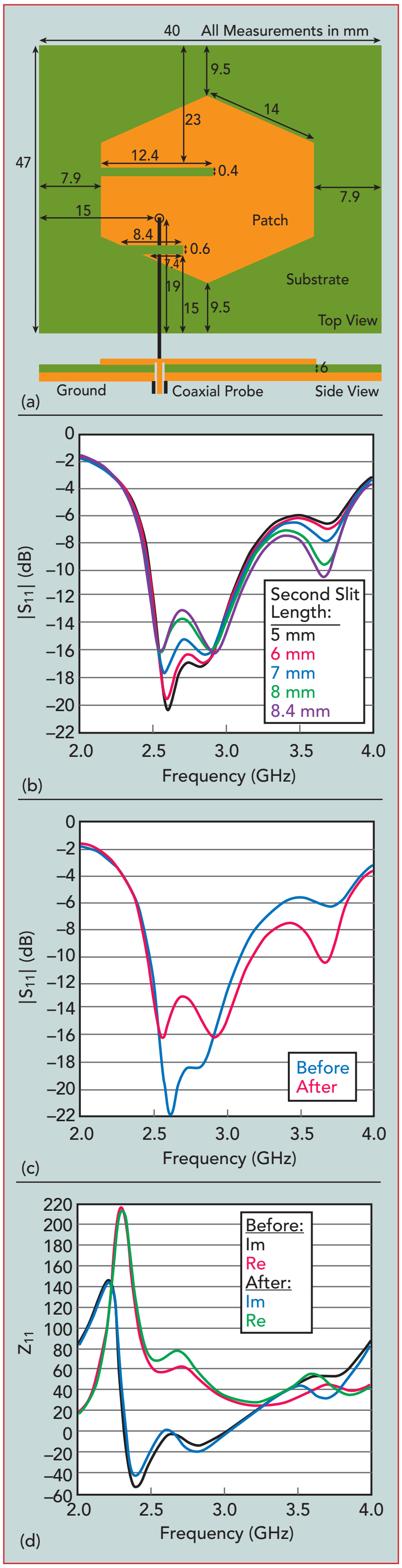
tance of the patch in an equivalent circuit of the antenna—increases. This causes the overall input impedance of the antenna to decrease. Impedance matching of the antenna improves[28-34] with the pin position in ***Figure 5a***, as observed in ***Figures 5b*** and ***c***.

Before shorting of the patch to ground, the modified antenna radiates linear polarization over the total resonant band, which is evident from the high axial ratio (see ***Figure 5d***). After shorting the patch, however, the current distribution from 3.63 to 3.77 GHz produces two orthogonal degenerate modes (TM_{01} and TM_{10}) with the same magnitudes; however, the phase difference between them is not 90 degrees, an essential condition for circular polarization. To satisfy the orthogonality condition, the position of the shorting pin is moved from the center toward the right edge of the patch, so the effective surface current path associated with the TM_{01} mode is slightly greater in one direction, compared to the TM_{10} mode in another direction. This causes the TM_{10} mode resonant frequency to shift slightly higher than the TM_{01} mode resonance, causing the phase difference of the two modes to equal 90 degrees. The condition required for circular polarization over the 3.63 to 3.77 GHz band is therefore satisfied.[35,36] The antenna modified with a shorting pin generates circular polarization from 3.63 to 3.77 GHz and linear polarization in the remaining portion of the operational frequency band.

Axial ratio and phase difference are measures of circular polarization. If the axial ratio is less than 3 dB and the phase difference is around 90 degrees over a frequency range, the antenna is considered to be circularly polarized over that range (see ***Figures 5d*** and ***5e***). To determine the optimum pin position, a parametric simulation using HFSS explored different pin positions on the radiating patch, observing $|S_{11}|$, input impedance and axial ratio. A pin position of 22.8 mm from the upper edge and 13.8 mm from the right edge of the substrate was found to be optimum.



▲ **Fig. 3** **Initial design with optimum probe position and first slit (a), variation of the resonant frequency bandwidth vs. first slit lengths and width = 0.4 mm (b), $|S_{11}|$ before and after first slit length optimization (c) and $|Z_{11}|$ before and after first slit length optimization (d).**



▲ **Fig. 4** **Design incorporating second slit (a), variation of the resonant frequency bandwidth vs. second slit lengths and width = 0.6 mm (b), $|S_{11}|$ before and after second slit length optimization (c) and $|Z_{11}|$ before and after second slit length optimization (d).**

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		0.832~0.96	1.4	8.2	±1.1	±0.7	± 9	16
		1.427~1.71	1.5	8.3	±0.9	±0.7	± 9	15
		1.71~2.2	1.5	8.5	±0.9	±0.8	±10	14
		2.496~2.69	1.5	8.7	±0.9	±0.7	± 9	13
		3.3~4.2	1.6	8.9	±1.0	±0.7	±12	13
		4.4~5	1.6	9.2	±1.0	±0.8	±12	13
SA-07-4B020080	4x4	2.4~2.5	1.4	7.3	±0.5	±0.3	± 4	14
		5.18~5.83	1.5	7.7	±0.6	±0.4	± 5	13
		5.9~7.25	1.5	7.8	±0.7	±0.5	± 6	13
SA-07-8B020080	8x8	2.4~2.5	1.5	11.2	±0.6	±0.4	± 8	13
		5.18~5.83	1.5	11.6	±0.8	±0.5	±10	12
		5.9~7.25	1.55	11.8	±0.9	±0.7	±12	12
SA-07-4B240430	4x4	24~43	2.0	12.4	±1.2	±2.0	±15	10

*Theoretical 6dB Included

Note: The connected components are available from MIcable which include the phase matched assemblies & low loss high isolation phase matched switches.

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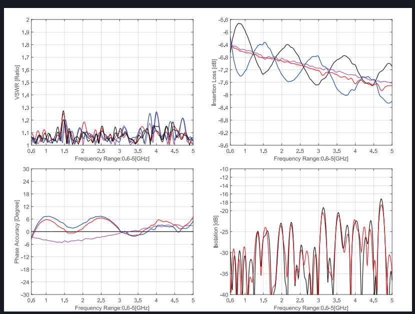

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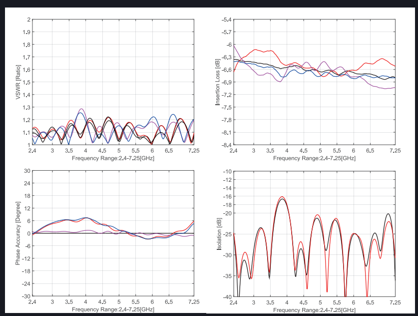

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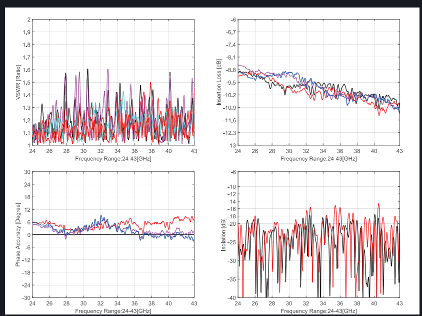

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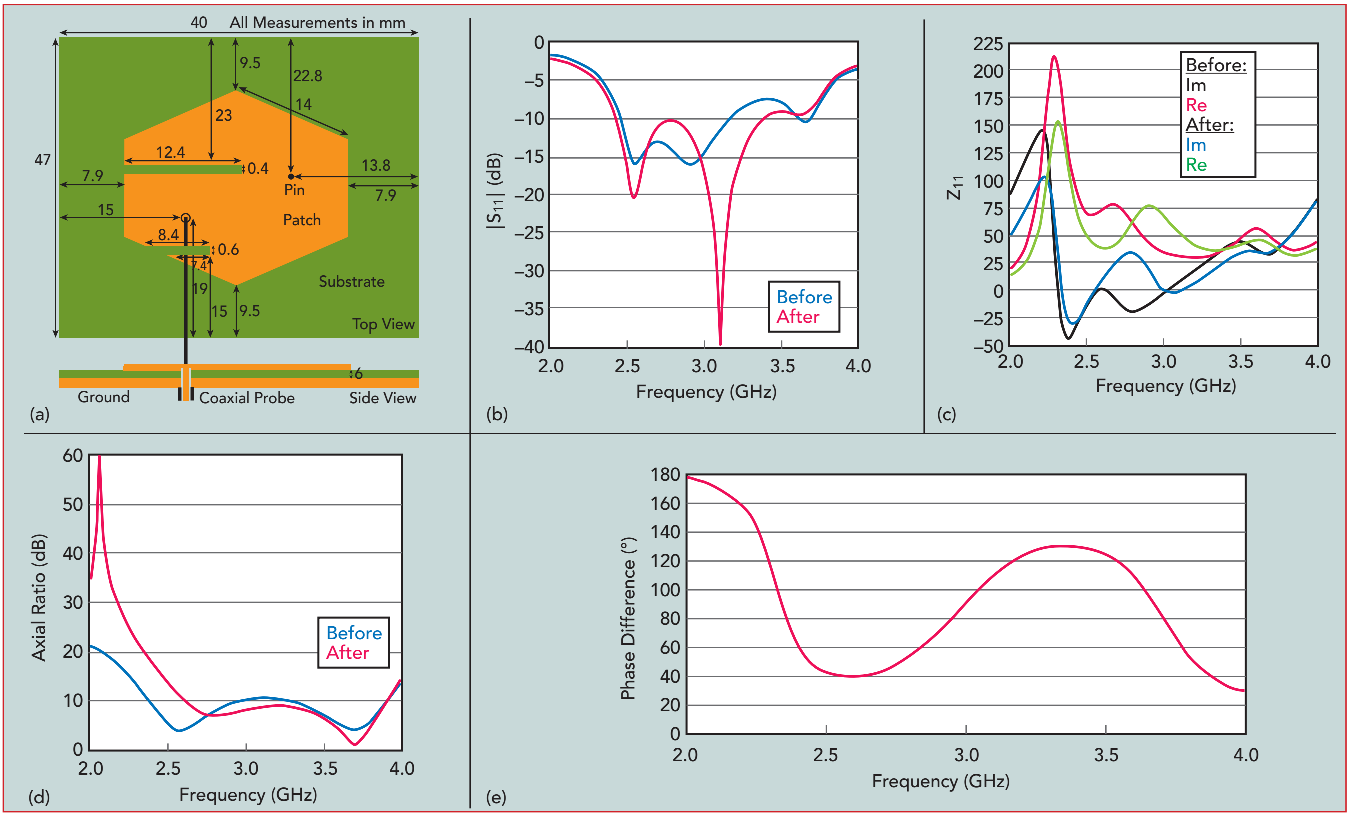


Fig. 5 Design with two slits and incorporating a shorting pin (a), showing the effect on $|S_{11}|$ (b), Z_{11} (c) and axial ratio (d). Phase difference between the TM_{10} and TM_{01} modes (e).

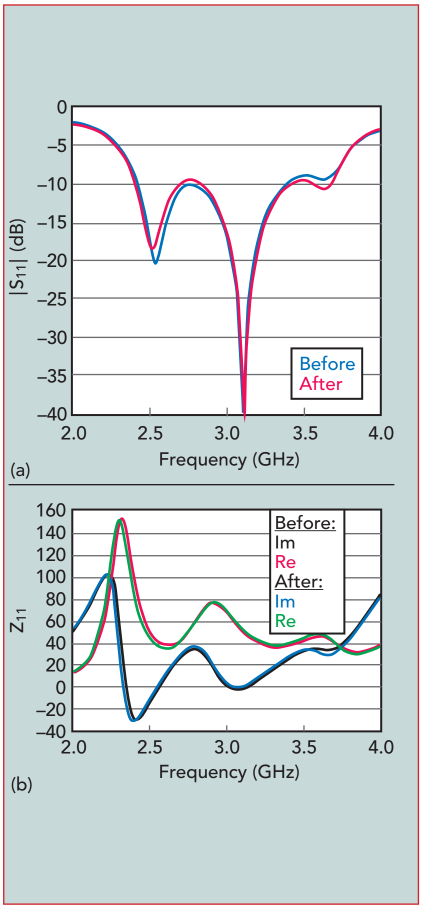


Fig. 6 Effect of the third slit on $|S_{11}|$ (a) and Z_{11} (b).

Effect of a Third Slit

From Figure 5b, the upper end of the 2.4 to 3.69 GHz frequency band has a return loss less than 10 dB due to poor impedance matching. Perturbing the patch with an optimized third slit (see Figure 1) shifts the input impedance closer to 50 Ω (see ***Figure 6***) and improves the impedance match at the upper end of the band.

MEASURED RESULTS

A prototype antenna (see ***Figure 7***) was measured using a Keysight E5071B network analyzer in an anechoic chamber. A comparison of the simulated and measured parameters are shown in ***Table 3***. $|S_{11}|$, radiation patterns, input impedance and gain with linear and circular polarization are shown in ***Figures 8*** through ***13***. The measurement results correspond well with the simulations. Still, small differences can be seen, which are attributed to connector soldering and the non-ideal

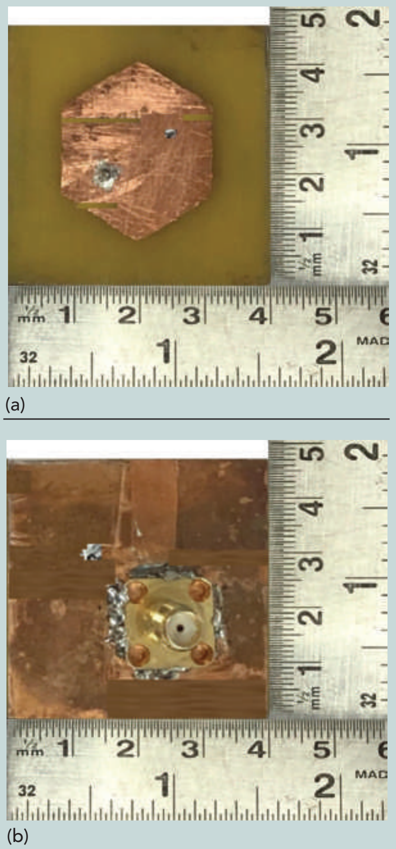


Fig. 7 Fabricated antenna top (a) and bottom (b) view.

measuring environment, which were not modeled. Figure 12 shows the antenna's simulated and measured linear polarized co-polarization (Co-pol) and cross-polarization (X-pol) patterns in a 2D plane at 2.5 GHz. Figure 13 shows the simulated and measured right-hand and left-hand circular polarization patterns in a 2D plane at 3.68 GHz.

EQUIVALENT CIRCUIT MODEL

A circuit model describing the antenna's operation (see ***Figure 14a***) provides insight into its construction. It is created by fitting the simulated S-parameters to an ADS software circuit model. A comparison of the $|S_{11}|$ of the circuit model with the HFSS simulation is shown in ***Figure 14b***.

CONCLUSION

A wideband microstrip patch antenna providing both linear and circular polarization was designed to cover multiple wireless applications. To determine the resonant frequency of the conventional hexagonal microstrip patch antenna, theoretical calculations with many combinations

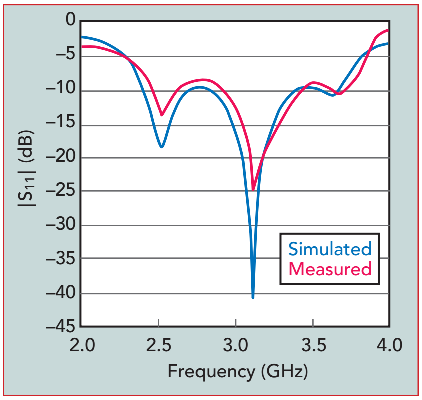
TABLE 3

ANTENNA SIMULATED VS. MEASURED PERFORMANCE

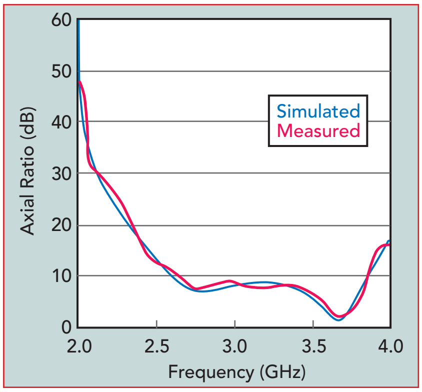
Parameter	Simulated	Measured
Overall Impedance Bandwidth: $\lvert S_{11} \rvert \leq -10$ dB	2.4 to 3.69 GHz 1.29 GHz, 42.4%	2.43 to 3.7 GHz 1.27 GHz, 41.4%
Linearly Polarized Bandwidth: $\lvert S_{11} \rvert \leq -10$ dB	2.4 to 3.62 GHz 1.22 GHz, 40.5%	2.43 to 3.62 GHz 1.19 GHz, 39.3%
Gain (dBi)	3.7 at 2.5 GHz	3.5 at 2.5 GHz
Circularly Polarized Bandwidth: Axial Ratio ≤ 3 dB	3.63 to 3.77 GHz 0.14 GHz, 3.8%	3.65 to 3.79 GHz 0.14 GHz, 3.76%
Gain (dBi)	5.9 at 3.68 GHz	5.5 at 3.68 GHz

of side lengths of the regular hexagonal patch were performed. Three slits were added to the radiating patch to enhance its impedance bandwidth, and the patch was shorted to ground with a copper pin, which changes a portion of the radiating band from linear to circular polarization. The final design achieved an impedance bandwidth of 42.4 percent, from 2.4 to 3.69 GHz as defined by $\lvert S_{11} \rvert \leq -10$ dB.

The antenna serves applications requiring a small antenna (47 × 40 × 6 mm^3) and a low manufacturing cost, such as Wi-Fi (2.4 to 2.485 GHz), Bluetooth (2.4 to 2.5 GHz), cellular (3.2 to 3.3 GHz), WiMAX (2.5 to 2.69, 3.3 to 2.4 and 3.4 to 3.69 GHz), military radar (2.7 to 2.9 GHz) and radar and navigation (2.9 to 3.1 GHz). ■



▲ **Fig. 8** Measured vs. simulated $\lvert S_{11} \rvert$.



▲ **Fig. 9** Measured vs. simulated axial ratio.

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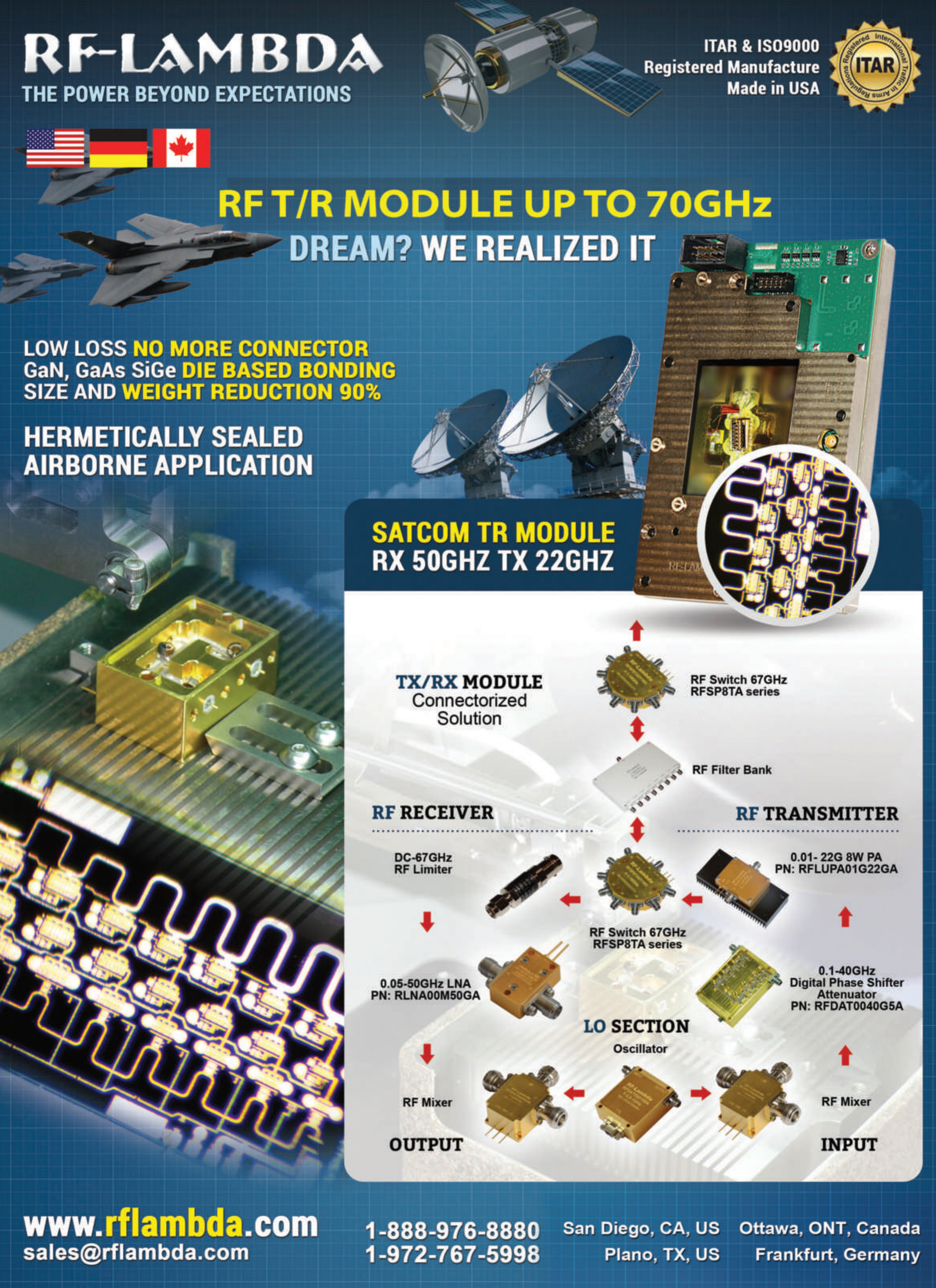

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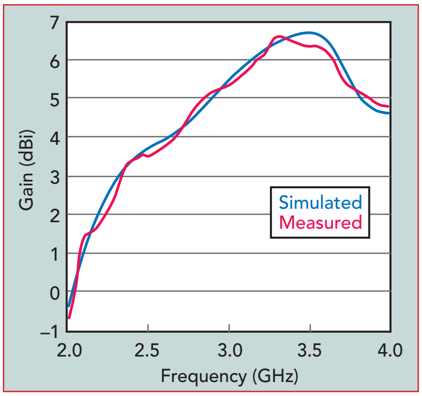

Fig. 10 Measured vs. simulated gain.

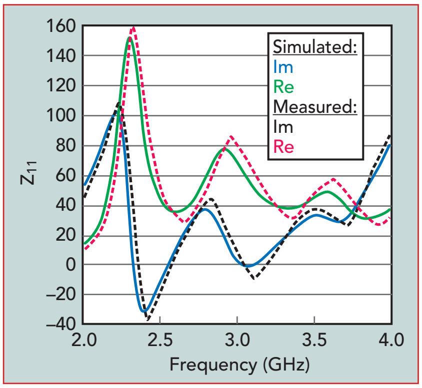

Fig. 11 Measured vs. simulated Z_{11}.

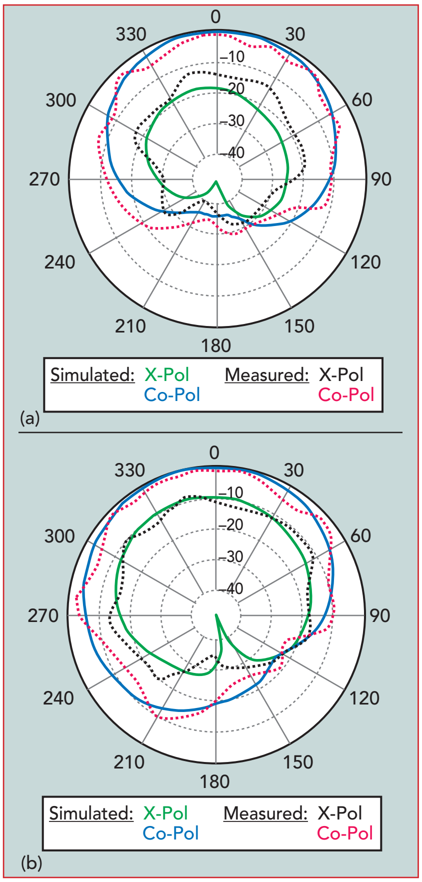

Fig. 12 Measured vs. simulated radiation patterns at 2.5 GHz: $\phi = 0$ (a) and $\phi = 90$ (b) degrees.

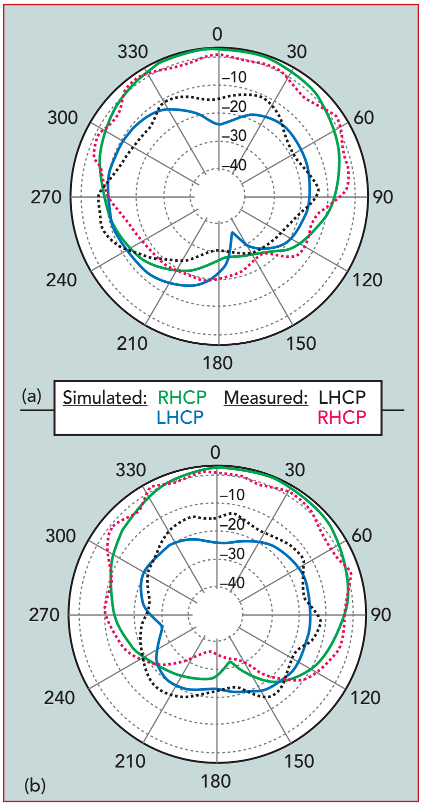

Fig. 13 Measured vs. simulated radiation patterns at 3.68 GHz: ϕ = 0 (a) and ϕ = 90 (b) degrees.

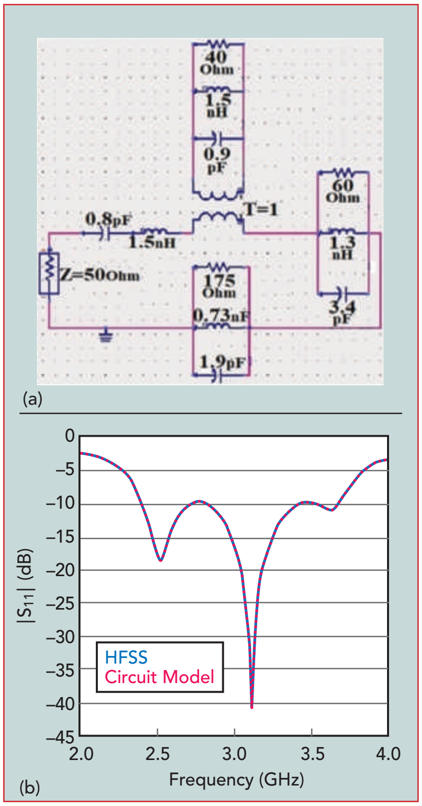

Fig. 14 Final antenna equivalent circuit model (a) and $|S_{11}|$ from the circuit model vs. HFSS simulation (b).

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Handheld Spectrum Analyzer Balances Price and Performance

Anritsu
Morgan Hill, Calif.

Anritsu Company has introduced the MS2070A, the latest member of its Field Master™ family of handheld spectrum analyzers. Built on a field-proven durable platform, the Field Master MS2070A provides necessary features and performance up to 3 GHz at an economical price. It is designed to conduct RF measurements in a variety of general-purpose field, lab and manufacturing environments.

With a dynamic range of > 105 dB at 2.4 GHz and 20 MHz analysis bandwidth, the MS2070A can capture and measure digitally-modulated signals used in commercial and military applications. Typical displayed average noise level with a built-in optional preamplifier of -167 dBm, coupled with a Third Order Intercept of +11 dBm and typical level accuracy of ±0.5 dB enables a full range of signals to be captured by the handheld spectrum analyzer. The MS2070A is designed to allow engineers to conduct standard swept spectrum analysis measurements simply and accurately up to 3 GHz. It features sweep speeds of up to 32 GHz/s in common low noise configurations.

PERFORMANCE IN HARSH ENVIRONMENTS

Leveraging the existing Field Master platform, the MS2070A is well-suited for the harsh environments associated with field applications. A ruggedized battery-powered instrument, the MS2070A has IP52 environmental protection when it is contained in the supplied soft carry case to withstand dust and water. It also has a 5 W RF damage level to protect the instrument from accidental overpowering.

Ruggedness extends to its IK08-rated display that can withstand accidental knocks or drops of tools on the screen. The 10-in. display has 1280 × 800 resolution and its multi-touch screen presents measurement results in large and clear formats. Common functions are always accessible and side menus collapse to maximize graphical results, as well.

Further complementing its field use, the MS2070A is compact and lightweight. It measures 290 × 212 × 96 mm and weighs 3.8 kg, making it easy to transport the handheld analyzer to remote sites.

WIDE SET OF STANDARD FEATURES

The Field Master MS2070A provides many of the key features typically found in higher-priced instruments. It has zero span to display TDD and pulsed signals with a narrow resolution bandwidth (RBW) of 10 Hz to 5 MHz for accurate measurements of power over time. Spectrograms are also standard, allowing spectrum versus time displays that

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RFIC Plenary Session, Reception, Industry Showcase	■					
Quantum Bootcamp	■					
AI/ML Bootcamp	■					
RF Bootcamp		■				
RFIC Technical Sessions and Interactive Forum		■	■			
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IMS Industry Showcase, Plenary and Welcome Reception		■				
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Workshops Technical Lectures RFIC Bootcamp Three Minute Thesis IMS Panel Sessions
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RFIC 2023 Plenary Speakers

Prof. Mau-Chung Frank Chang
Wintek Chair in Electrical Engineering and Distinguished Professor, *University of California, Los Angeles (UCLA)*

Dr. Todd Younkin
President & CEO, *Semiconductor Research Corporation (SRC)*

result in accurate detection of intermittent interferers.

As many as six traces can be set simultaneously with different detectors. Averaging can be applied to each, as well. Up to 12 markers are provided, so signals of interest can be highlighted and monitored for variation over time, relative to themselves and other signals. Alerts for new interfering or lost signals are generated automatically. Additionally, upper/lower, envelope and alarm limits are standard on the MS2070A to optimize long-term spectrum monitoring. Several "smart" measurements are also standard in the Field Master MS2070A. The handheld spectrum analyzer can conduct occupied bandwidth (OBW), channel power and adjacent channel power using just a few keystrokes.

REMOTE CONTROL AND CONNECTIVITY

Ethernet and USBTMC interfaces are standard on the Field Master MS2070A, providing flexible options for remote instrument control. The USBTMC interface allows the Field Master MS2070A to be controlled from a smartphone, tablet or PC with an Android operating system. A Wi-Fi 802.11b/g/a/n interface is available as an option to connect to wireless routers for common applications, including downloading digital maps and automatic software updates.

FOR FIELD AND BENCH USE

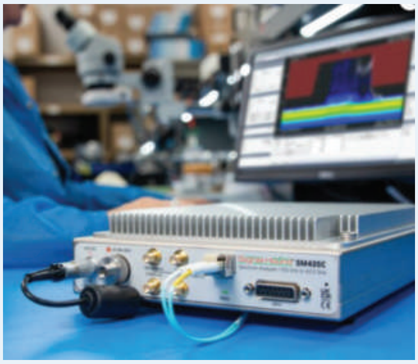
The Field Master MS2070A can be used for a variety of field applications. It can conduct basic transmitter testing, including determining signal presence, modulation bandwidth and symmetry and harmonics and spurious. Interference hunting to determine if unwanted signals are in a spectrum can also be performed with the handheld spectrum analyzer. Cellular network operators can also configure the MS2070A with a PIM stick for PIM hunting.

In lab and manufacturing environments in which portability and space are at a premium, the MS2070A can be used for standard RF measurements. It has the performance to conduct EMC pre-compliance testing of new PCBs during electronic circuit development. The spectrum analyzer can also serve as a general-purpose instrument for routine measurements during product design and test.

FIELD MASTER FAMILY

The MS2070A is the base model in the Field Master family. A mid-range model, the MS2080A, operates up to 4 GHz and integrates a spectrum analyzer, real-time spectrum analyzer (RTSA), cable and antenna analyzer and LTE/5G base station tester into a single battery-powered instrument. The high-end Field Master Pro MS2090A RTSA delivers continuous frequency coverage from 9 kHz to 54 GHz. It can also be configured with optional 110 MHz RTSA, IQ streaming and pulse analysis.

Anritsu
Morgan Hill, Calif.
www.anritsu.com



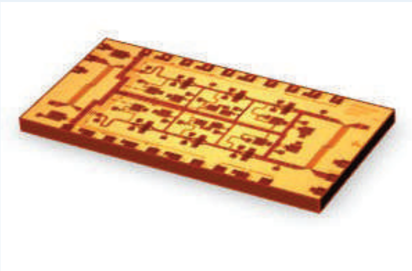
Network-Capable mmWave Spectrum Analyzer

Signal Hound's SM435C is a high performance, real-time spectrum analyzer and monitoring receiver with a 10 Gigabit Ethernet SFP+ port, enabling the SM435C to communicate with a PC over long distances using a fiber optic cable. This analyzer features device control and data transfer via an SFP+ connection, rather than a USB connection. The analyzer contains a 20 MHz to 43.5 GHz sub-octave preselector that allows tuning from 100 kHz to 43.5 GHz. The SM435C has 160 MHz continuous streaming I/Q over 10GbE SFP+, with 110 dB of dynamic range, 1 THz/sec sweep speed at 30 kHz resolution bandwidth (using Nuttall windowing) and phase noise performance low enough to contribute less than 0.1 percentage point error to error vector magnitude measurements. The spectrum analyzer also contains a GPIO port for antenna switching. The form factor of the SM435C allows it to fit in the corner of a test bench or a conveniently sized enclosure.

The SM435C targets applications involving 5G mmWave monitoring and analysis, 24 GHz ISM frequency monitoring, complete Ka-Band spectrum testing and analysis of emerging and new high frequency RF signals. For technical surveillance countermeasures-specific applications, the SM435C is also compatible with the Kestrel and SCEPTRE software packages to provide an affordable and powerful countermeasure solution.

The SM435C includes all the required operating software for operation. As with other Signal Hound devices, the proprietary Spike™ software provides the device controls, signal visualization display and data export tools. The SM435C comes with a signed calibration certificate and a printed packet of calibration data.

Signal Hound
Battle Ground, Wash.
www.signalhound.com/sm435c



3.5 W, V-Band, GaN Power Amplifier MMIC

Nxbeam expands its MMIC portfolio with the release of a new GaN V-Band power amplifier MMIC. The NPA4010-DE operates from 47 to 52 GHz and provides an average saturated output power of 3.5 W, average power-added efficiency of 23 percent and average linear gain of 24 dB. The balanced design configuration uses Lange couplers to provide input and output return losses of better than 15 and 13 dB, respectively.

The output power level of this MMIC makes it ideal for point-to-point V-Band communication links and satellite communications ground terminals. The part can be used as a driver amplifier or can be easily power combined given its balanced design configuration to achieve higher output power levels.

The design incorporates three independently controlled amplifier stages and was designed to offer customers the flexibility to tailor linear power performance over a variety of modulations and use cases.

The RF input and RF output are matched to 50 Ω with DC blocking capacitors for easy system integration. Bond pad and backside metallization are Au-based for compatibility with eutectic die attachment methods. The chip dimensions are 2.85 x 1.45 x 0.075 mm^3.

Since 2018, Nxbeam has been developing high performance GaN power amplifier MMICs and higher-level products for the satellite and 5G communications markets. Its mission is to deliver the next generation of wireless communication infrastructure products to power the future of information communication technology.

Nxbeam Inc.
Los Alamitos, Calif.
www.nxbeam.com

Check out Abracon's New Interactive Antenna Catalog!

Abracon's new interactive antenna catalog features over 45 new antennas, antennas supporting 5G protocol, video-embedded resources, clickable links to part number pages and easy access to datasheets and inventory.

Abracon
https://abracon.com/interactive-antenna-catalog

Fairview Microwave Celebrates 30 Years in Business

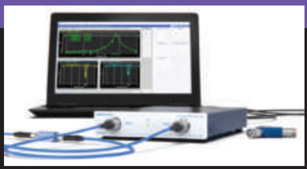
Founded in 1992, Fairview Microwave (originally the Sun Moon Electronics Company or SM Electronics) announced it is celebrating 30 years in business.

Fairview Microwave
www.fairviewmicrowave.com

Mini-Circuits eVNA-63+ Vector Network Analyzer

Mini-Circuits' eVNA-63+ is a high performance, software-controlled 2-port vector network analyzer (VNA) operating from 300 kHz to 6 GHz.

Mini-Circuits
www.youtube.com/watch?v=Cc5o9tcYvek&t



Pasternack Celebrates 50th Anniversary

To commemorate this milestone anniversary, the company recently interviewed Murray Pasternack to get all the details on the company's inception and growth.

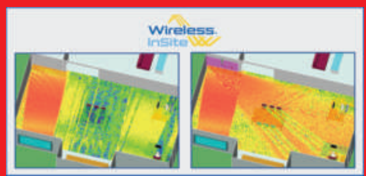
Pasternack
bit.ly/3FIFBcA

Top Blog Posts of 2022: Connectivity Reigns

What do lost car keys, Wi-Fi speed and antennas have in common? Check out Qorvo's top five blog posts of 2022 to find out!

Qorvo
www.qorvo.com/design-hub/blog/2022-dec-20-top-blogs/

Remcom's New Version of Wireless InSite 3D Wireless Prediction Software



Remcom announced a new version of Wireless InSite 3D Wireless Prediction Software with propagation analysis for engineered electromagnetic surfaces, allowing modeling of passive metasurfaces designed to optimize wireless communication coverage by manipulating how signals propagate through a scene.

Remcom
www.remcom.com/wireless-insite-em-propagation-software

Wireless Communications Calculator

The Rohde & Schwarz wireless communications calculator is an essential tool for all wireless design engineers. It covers the most important cellular and non-cellular standards including 5G NR, LTE, Wi-Fi and Bluetooth. Download now for iOS and Android.

Rohde & Schwarz
www.rohde-schwarz.com/wcc

25 Years of Successful Cooperation

Rosenberger and bda connectivity recently celebrated 25 years of successful cooperation in the field of triax measurement technology: triaxial CoMet measuring tube systems, developed and manufactured by Rosenberger and marketed by bda.

Rosenberger
www.rosenberger.com

Times Microwave Systems Launches Newly Redesigned Website

Times Microwave Systems has launched a brand-new, completely redesigned website configured to provide user-friendly education across the wide range of industries where the company's technology, expertise and products are used.

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COMPONENTS/MODULES

Butler Matrix
VENDORVIEW

Model KBM9100400 covers the ultra-wideband frequency range from 10 to 40 GHz and provides ±1.2 dB of maximum amplitude imbalance and maximum phase imbalance of ±15 degrees. This model exhibits low insertion loss of 12 dB with low VSWR of 2.0:1 dB and high isolation of 12 dB. This Butler Matrix is a compact package measuring just 3.68 (L) × 2.80 (W) × 0.81 in. (H) and comes with standard 2.4 mm coaxial female connectors.
KRYTAR Inc.
www.krytar.com

C-Band Filter

MCV Microwave introduces MCV Blue, a C-Band filter for protection against 5G and terrestrial interference. The filter passes from 4000 to 4200 MHz while providing outstanding rejection both below and above the passband. The filter exhibits very low insertion loss while maintaining a compact size. It is easily installed between the feed and LNB for new and existing installations. The filter is environmentally sealed and moisture resistant (IP66).
MCV Microwave
www.mcv-microwave.com

Step Attenuators
VENDORVIEW

Pasternack has expanded its portfolio of step attenuators for use in high-reliability applications requiring precise control of signal levels, including precision measurements, prototyping and characterization product systems and instrumentation. They feature a maximum VSWR of 1.4:1, a maximum insertion loss of 1 dB and attenuation accuracy of ±5 dB, making them well-suited for high-reliability applications requiring accurate control of attenuation values. Additional performance characteristics include high power and wide coverage with a 2 W power rating and an operating frequency range up to 18 GHz.
Pasternack
www.pasternack.com

Limiter
VENDORVIEW

Quantic PMI model no. LM-20M20G-18-20WP-5W-MAH is a limiter with a frequency range of 20 MHz to 20 GHz. This unit has an insertion loss of 1.55 dB, a VSWR of 1.9:1, an input power of 5 W, and a recovery time of 25 ns. It has SMA female connectors and the housing size is 0.50" × 0.50" × 0.22".
Quantic PMI
www.pmi-rf.com

Band Reject (Notch) Filters

RLC Electronics has introduced higher frequency band reject (notch) filters, designed to operate over the frequency range of .01 to 40 GHz. These filters are characterized by having the reverse properties of bandpass filters and are offered in multiple topologies. The filters are available in compact sizes and are constructed to operate over the most severe military environmental conditions. Filters are tailored to specific customer needs (electrical, mechanical and environmental), with insertion loss typically less than 1 dB and VSWR less than 1.5:1.
RLC Electronics
www.rlcelectronics.com

CABLES & CONNECTORS

Field-Replaceable Connectors
VENDORVIEW

Fairview Microwave has introduced a new series of field-replaceable connectors designed for a variety of RF/microwave applications. Fairview's new series of field-replaceable connectors allows for easy replacement of damaged connectors without needing to access sealed components. The connectors' EMI gaskets protect the internal parts of devices from electromagnetic interference. These field-replaceable connectors offer frequency coverage up to 65 GHz and feature 1.85, 2.4, 2.92 mm and SMA connectors. Contacts for the connectors mate with five-pin diameters ranging from 0.009" to 0.036".
Fairview Microwave
www.fairviewmicrowave.com

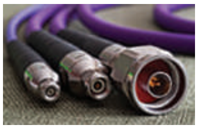
SMP Microwave Cable Assemblies
VENDORVIEW

MIcable C29F series 40 GHz high performance SMP microwave cable assemblies have a wide operating frequency range up to 40 GHz with excellent electrical performance, the typical cable loss is 4.92 dB/m at 40 GHz, the VSWR is less than 1.35:1 at 40 GHz, the shielding effectiveness is greater than 90 dB and amplitude and phase stability are less than ±0.1 dB and ±3 degrees, respectively. Also, the small cable diameter, small bending radius (5 mm) and blind-mated structure make them easy to install. It is an ideal choice for equipment internal connection, module interconnection and compact space installation.
Fujian MIcable Electronic Technology Group Co. Ltd.
www.micable.cn

The EESeal+®

Meet the newest addition to the EESeal® family of EMI filter connector inserts: the EESeal+. Achieve enhanced filtering for demanding high frequency requirements (up to 20 to 40 GHz) and greater attenuation needs (up to 45 to 50 dB). The EESeal+ utilizes conductive silicone rubber to provide an extremely low inductance ground plane. Like the original EESeal, it can be installed in seconds, maintains the environmental seal of the host connector and is proven against MIL-STD and DO-160 requirements.
Quell
www.eeseal.com

Ruggedized Cable Assemblies
VENDORVIEW



DuraWave™ PS are ruggedized cable assemblies, ideal for on-site field testing, harsh production environments and the testing laboratory. The PS series distinguishes itself by guaranteeing a maximum phase and insertion loss stability specification. Designed to offer durability and flexibility, DuraWave™ PS cables are jacketed with a material rated for 125°C continuous use. These assemblies are available across the frequency spectrum with a broad range of connectors in both male and female configurations.
Swift Bridge Technologies
www.swiftbridgetechnologies.com

NewProducts

AMPLIFIERS

S-Band 120 kW Pulse Transmitter

VENDORVIEW

Empower RF Systems sets the bar for extreme high-power solid state COTS amplifiers. The Model 2236 is liquid cooled and combines the output of two six-foot cabinets with each cabinet combining sixteen 2U power amplifiers. Lower and higher power versions of this amplifier are available due to the scalable, modular design. Operating from 2800 to 3500 MHz, the flexible pulse handling capabilities of this fielded system includes 20 percent duty cycles with pulse widths from 200 ns to 500 us and PRFs up to 500 kHz.

Empower RF Systems
www.empowerrf.com

1 KW, Solid-State, L-Band, Pulse Amplifier

VENDORVIEW

Exodus Advanced Communications' AMP4087P-1KW pulse amplifier is designed for pulse, EMC/EMI MIL-STD 461 and automotive pulse radar applications. Providing superb pulse fidelity and up to 100 usec pulse widths. Duty cycles to 10 percent with a minimum 60 dB gain. Available monitoring parameters for forward/reflected power in watts and dBm, VSWR, voltage, current, temperature sensing for outstanding reliability and ruggedness in a compact 3U chassis.

Exodus Advanced Communications
www.exoduscomm.com

175 Coaxial Amplifier

VENDORVIEW

Mini-Circuits' model ZVA-02653G+ is a 2 to 65 GHz coaxial amplifier with 21 dB typical gain from 2 to 60 GHz and 19 dB from 60 to 65 GHz. Supplied with 1.85 mm female connectors, the amplifier delivers typical output power at 1 dB compression of +16.5 dBm from 2 to 40 GHz, +14 dBm from 40 to 60 GHz and +9.5 dBm from 60 to 65 GHz. It operates from a single-supply of +10 to +15 VDC and includes reverse-and over-voltage DC protection.

Mini-Circuits
www.minicircuits.com

Broadband Low Noise Amplifier

Model ABL0800-50-4008 is a two stage MMIC based low noise amplifier module. It offers 40 dB of linear gain and 0.8 dB noise figure with excellent gain flatness and input/output return loss. The unit has a built-in voltage regulator and operates with a single DC power supply voltage. The package size of the amplifier is 1.5 × 1.0 × 0.4".

Wenteq Microwave
www.Wenteq.com

SOURCES

E-Band Noise Source

VENDORVIEW

Providing noise power flatness of ±1.5 dB from 60 to 90 GHz, model STZ-12-IT2 is an E-Band noise source that delivers 13 dB excess noise ratio. The included compact isolator provides output return loss of 15 dB typically. DC power is +28 VDC at 30 mA. A TTL trigger input supports on/off modulation at repetition rates up to 1 kHz. The

noise source measures 5.25 × 1.20 × 0.81 in. and includes a WR-12 waveguide output with an anti-cocking flange.
Eravant
www.eravant.com

PACKAGING

7KF Series Machines

WEST BOND'S new 7KF series machines are convertible between ball bonding and wedge bonding, presenting wire at both 45 degrees for optimal loop and tail control, and 90 degrees for deep access and ribbon bonding. The programming of each setting, operation of the machine, action prompts and fault diagnostic information is displayed and input on the machine's 7-in. capacitive touch sensing LCD. Programmable force (15 to 135 g), pure vertical Z-motion and programmable radiant tool heat.
WEST BOND
www.westbond.com

ANTENNAS

HyperLOG® Pro Antenna Series

VENDORVIEW

If you are looking for the dream partner for your spectrum analyzer, you will find it in the new bi-directional HyperLOG® Pro antennas from Aaronia. This proven antenna family with improved performance and directivity, so far consisting of five antennas from 2 GHz to maximum 40 GHz, is extended by four additional versions with a frequency range from 700 MHz up to 26.5 GHz maximum. All HyperLOG® Pro antennas offer an unbeatable price/performance ratio combined with an unprecedented mix of performance and manageability.
Aaronia AG
www.aaronia-shop.com

TEST & MEASUREMENT

Electromagnetic Field Measurements

The new Narda FieldMan is a handy instrument for reliable and precise isotropic EMF measurements from 0 to 90 GHz. It will deliver authoritative results even for future applications in the fields of health and safety at work and in the environment. Intelligent features like the large sunlight readable 5-in. color display ensure that the operating concept, handling and economy are all first rate, resulting in an excellent total cost of ownership. Its digital probe interface eliminates the need for base unit calibrations.
Narda Safety Test Solutions GmbH
www.narda-sts.com

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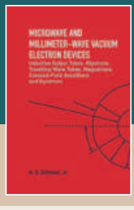

Bookend

Microwave and Millimeter-Wave Vacuum Electron Devices

By: Dr. A. S. Gilmour, Jr.

The summary of outstanding knowledge and experience built-up over a lifetime of active involvement in the research, design, development and application of RF vacuum electron devices, also known as microwave tubes, is the gift Dr. A. S. Gilmour, Jr., IEEE fellow, is offering to us with this impressive 895-page volume. Through a short yet interesting preface, Dr. Gilmour gives us a first historical glimpse, taking us back to a time when microwave tube specialists thought they could be taken out of business, as solid-state technologies were emerging. Yet, decades after, vacuum electron devices are still in heavy utilization and have continuously proven their worthiness and improved their performance. This book contains a balance of theoretical and practical material, enabling the reader to understand those vacuum electron devices that are in use today, as well as some that have been phased out and those that may be needed for new applications. It benefits from a didactic flow and well-thought structure, leveraging the previous publications by the author, as well as his hundreds of delivered courses to thousands of engineers and scientists worldwide. Chapter 1, the introduction, is of particular interest as an overview of all existing microwave tube technologies, providing a synthetic description of the average power/frequency range of relevance for the various devices, as well as indicators of their performance and how these evolved over the past nine decades. Through the next eight chapters, Dr. Gilmour takes us through all the key concepts and equations necessary to accurately understand the operation of vacuum electron devices from the base electromagnetic theory to the need and requirement for vacuum, working principles and implementations of thermionic and cold cathodes, electron guns and beam modulation techniques, as well as the principles of interaction between the beam and RF circuitry. From chapter 10 to the end, each major tube technology: inductive output tubes, klystrons, helix and coupled-cavity traveling wave tubes, magnetrons, crossed-field amplifiers and gyrotrons is passed under Dr. Gilmour's microscope, providing significant details on historical designs and the evolution towards modern devices, giving examples of specific realizations, along with their main parameters and ways to understand and calculate the relevant performance metrics. The vast content covered by the book makes it a reference work, valuable for engineers who want to get an in-depth understanding of the subject matter or develop and grow related working knowledge.

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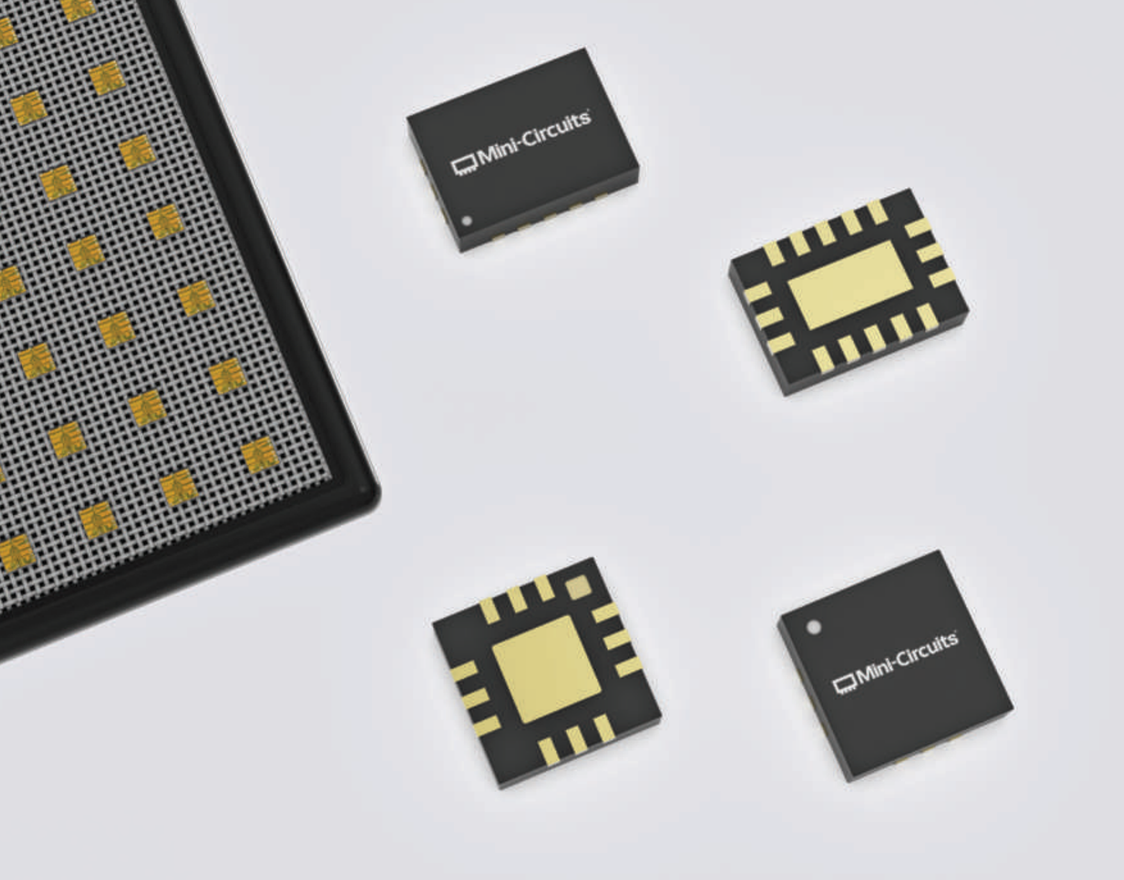

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EECL: A lean, flexible and cost-effective approach to RF design and manufacture for space and commercial markets

European Engineering and Consultancy Limited (EECL) was established in 2016 by Dr. Ben Kieniewicz to address a perceived gap in the RF and microwave market. The company provides fast, flexible and cost-effective RF and electronic design, test and manufacturing services, specializing in the satellite and aerospace sector industry. Despite being a relatively young company, EECL has been involved in several large and complex projects, including lunar space missions and leading-edge design and build of quantum computing hardware. Notable successes have included two years of design and consultancy work on the Airbus OneWeb channelizer RF payload, for which much of the design work for the 648 satellites in orbit was carried out by EECL. The company has also been selected to provide the hardware for the experimental GPS payload for the European Space Agency's (ESA) Lunar Pathfinder mission.

Most recently the company signed a contract to supply low noise amplifiers (LNAs) to Surrey Satellite Technology (SSTL) for the front-end receiver of the HydroGNSS Scout Earth Observation payload. ESA's second Earth observation Scout mission, HydroGNSS features a receiver that collects GPS signals reflected from different areas on the Earth's surface and uses a reflectometry technique to make measurements of key hydrological climate variables. The entire Earth's biomass and soil moisture content will be measured by this technique. The low noise figure of the EECL LNA is key to ensuring the HydroGNSS receiver has enough signal sensitivity to be able to perform the metrics and thus provide crucial data on the Earth's biomass.

EECL's headquarters are in Kingston-upon-Thames, which is located to the south of London in the U.K. The facility has a certified ISO Class 7 cleanroom incorporating assembly and test areas and an ISO Class 8 laboratory. Both areas have full ESD-safe working areas.

In the test area, the company has invested in a full range of automated electronic and RF/microwave test equipment, mainly from Keysight Technologies, including VNAs, signal generators, noise figure meters, oscilloscopes and spectrum analyzers, providing measurement capability at frequencies up to 44 GHz. Additional specialized equipment includes TDR measurement equipment, various antennas and calibration references.

The manufacturing and assembly area features a thermal test chamber to carry out environmental testing over -45°C to +180°C, small vacuum chambers, an infrared BGA surface mount rework station, a solder print station, a range of solder stations (hot air, infrared, Metcal irons), hot plate, reflow oven, cable stripping machine, ultrasonic cleaner and a dry compressed air system. Among the diagnostic equipment available are microscopes, a high-resolution imaging camera and a thermal camera. There are also humidity- and temperature-controlled storage facilities, meaning that all aerospace electronic parts and products can be stored in a temperature-controlled environment with less than 1 percent humidity.

Satellite manufacturers are demanding designs that offer better performance, lower cost and quicker turn-around times while also employing state-of-the-art technologies and processes to address the newly emerging space markets. Combining extensive experience of delivery into real space missions with the implementation of leaner working practices, EECL prides itself on offering a "right-first-time" approach to the production of fully compliant hardware at a competitive cost, without any compromise on product assurance or quality. It also applies the same high standards and principles to serve a range of commercial RF and microwave markets.

EECL provides affordable access and a route to world-class electronic design, RF and mechanical engineering services to companies of all sizes in any sector of the industry. The scale of its projects can vary from ones with just a few hours duration to complex long-term design, simulation or full product development engagements.

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D8454	8-Way	370-450	10,000	50,000	0.25	1.30:1	3 1/8" EIA, N-Female
D5320	12-Way	470-860	500	5,000	0.30	1.30:1	All N-Female
D10119	4-Way	700-4200	2,000	15,000	0.30	1.35:1	13-30 DIN-Female, N-F
D10603	32-Way	900-925	50,000	150,000	0.15	1.25:1	WR975, 7/16-Female
D10795	32-Way	900-930	25,000	150,000	0.25	1.20:1	WR975, 4.3-10-F
D9710	8-Way	1000-2500	2,000	10,000	0.30	1.40:1	1 5/8" EIA, N-Female
D8182	5-Way	1175-1375	1,500	25,000	0.40	1.35:1	1 5/8" EIA, N-Female
D6857	32-Way	1200-1400	4,000	16,000	0.50	1.35:1	1 5/8" EIA, N-Female
D11896	4-Way	2000-2120	4,000	40,000	0.25	1.40:1	WR430, 7/16-Female
D11828	4-Way	2400-2500	3,000	25,000	0.20	1.25:1	WR340, 7/16-Female
D10851	8-Way	2400-2500	8,000	50,000	0.20	1.25:1	WR340, 7/16-Female
D11433	16-Way	2700-3500	2,000	20,000	0.30	1.35:1	WR284, N-Female
D11815	16-Way	2700-3500	6,000	40,000	0.30	1.35:1	WR284, N-Female
D12101	6-Way	2750-3750	2,000	20,000	0.35	1.40:1	WR284, N-Female
D9582	16-Way	3100-3500	2,000	16,000	0.25	1.50:1	WR284, N-Female
D12102	6-Way	5100-6000	850	4,500	0.35	1.35:1	WR159, N-Female
D12484	6-Way	8200-8600	600	700	0.35	1.25:1	WR112, SMA-Female
D12485	6-Way	9000-11,000	500	700	0.40	1.35:1	WR90, SMA-Female

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