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December 2023

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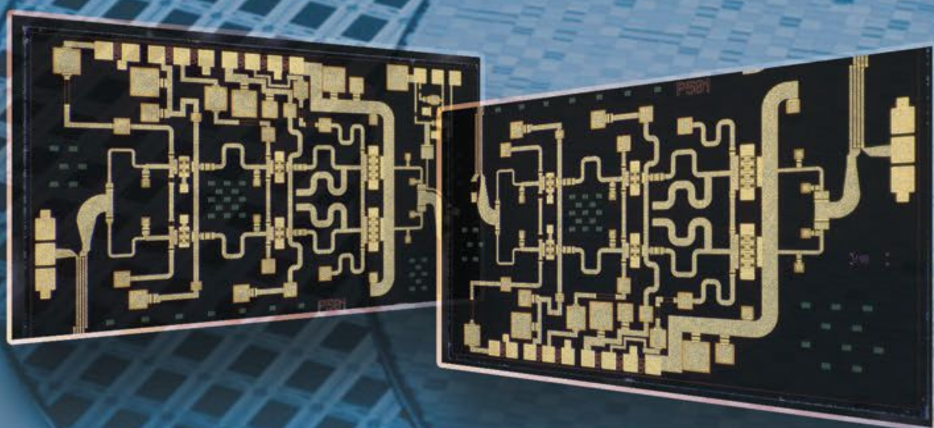


Miller MMIC is a global provider of RF semiconductor solutions with expertise in GaAs and GaN processes. We offer a diverse range of products tailored to various wireless applications. Our product lineup encompasses a wide array of offerings, including Low Noise Amplifiers, Distributed Amplifiers, Power Amplifiers, Driver Amplifiers, RF Switches, RF PIN Diode Switches, and numerous other voltage- and digitally-controllable RF components.

PN: MMW5FP
RF GaAs MMIC DC-67GHz

RF Distributed Low Noise Amplifiers

PN	Freq Low (GHz)	Freq High (GHz)	Gain (dB)	NF(dB)	P1dB (dBm)	Voltage (VDC)	Current (mA)	Package
MMW001T	DC	20.0	17~19	1~3.5	23 @ 10GHz	8.0	145	die
MMW4FP	DC	50.00	16.00	4.00	24.00	10	200	die
MMW507	0.20	22.0	14.0	4 - 6	28.0	10.0	350	die
MMW508	DC	30.0	14.0	2.5dB @ 15GHz	24.5	10.0	200	die
MMW509	30KHz	45.0	15.0		20.0	6.0	190	die
MMW510	DC	45.0	11.0	4.5	15.5	6.0	100	die
MMW510F	DC	30.00	20.00	2.50	22.00			die
MMW511	0.04	65.0	10.0	9.0	18.0	8.0	250	die
MMW512	DC	65.0	10.0	5.0	14.5	4.5	85	die
MMW5FN	DC	67.00	14.00	2.00	19.00	4.5	81	die
MMW5FP	DC	67.00	14.00	4.00	21.00	8	140	die
MMW011	DC	12.0	14.0		30.5	12.0	350	die

Low Noise Amplifiers

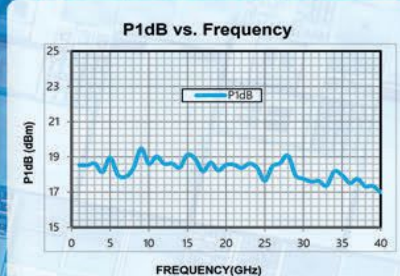
PN	Freq Low (GHz)	Freq High (GHz)	Gain (dB)	NF(dB)	P1dB (dBm)	Voltage (VDC)	Current (mA)	Package
MML040	6.0	18.0	24.0	1.5	14.0	5.0	35	die
MML058	1.0	18.0	15.0	1.7	17.0	5.0	35	die
MML063	18.0	40.0	11.0	2.9	15.0	5.0	52	die
MML080	0.8	18.0	16.5/15.5	1.9/1.7	18/17.5	5.0	65/40	die
MML081	2.0	18.0	25/23	1.0/1.0	16/9.5	5.0	37/24	die
MML083	0.1	20.0	23.0	1.6	11.0	5.0	58	die

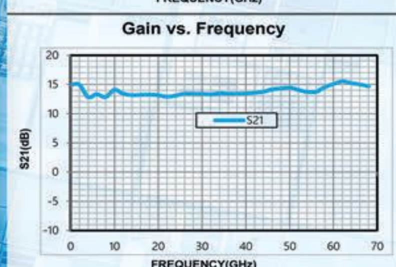
RF Driver Amplifier

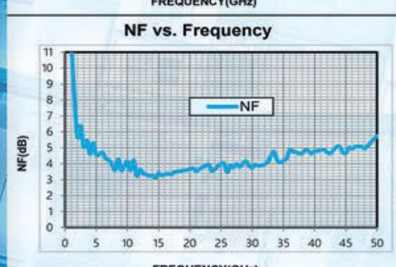
PN	Freq Low (GHz)	Freq High (GHz)	Gain (dB)	NF(dB)	P1dB (dBm)	Voltage (VDC)	Current (mA)	Package
MM3006	2.0	20.0	19.5	2.5	22.0	7.0	130	die
MM3014	6.0	20.0	15.0	-	19.5	5.0	107	die
MM3017T	17.0	43.0	25.0		22.0	5.0	140	die
MM3031T	20.0	43.0	20.0		24.0	5.0	480	die
MM3051	17.0	24.0	25.0	-	25.0	5.0	220	die
MM3058	18.0	40.0	20/19.5	2.5/2.3	16/14	5/4	69/52	die
MM3059	18.0	40.0	16/16	2.5/2.3	16/15	5/4	67/50	die

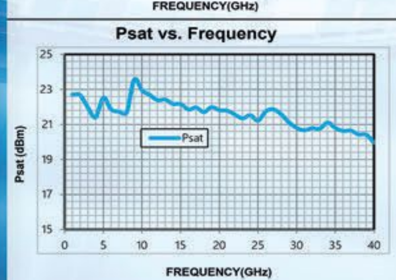
GaAs Medium Power Amplifier

PN	Freq Low (GHz)	Freq High (GHz)	Gain (dB)	P1dB (dBm)	Psat (dBm)	Voltage (VDC)	Current (mA)	Package
MMP107	17.0	21.0	19.0	30.0	30.0	6.0	400	die
MMP108	18.0	28.0	14.0	31.5	31.0	6.0	650	die
MMP111	26.0	34.0	25.5	33.5	33.5	6.0	1300	die
MMP112	2.0	6.0	20.0	31.5	32.0	8.0	365	die
MMP501	20.0	44.0	15.0	27 -- 32	29 - 34	5.0	1200	die
MMP502	18.0	47.0	14.0	28.0	30.0	5.0	1500	die









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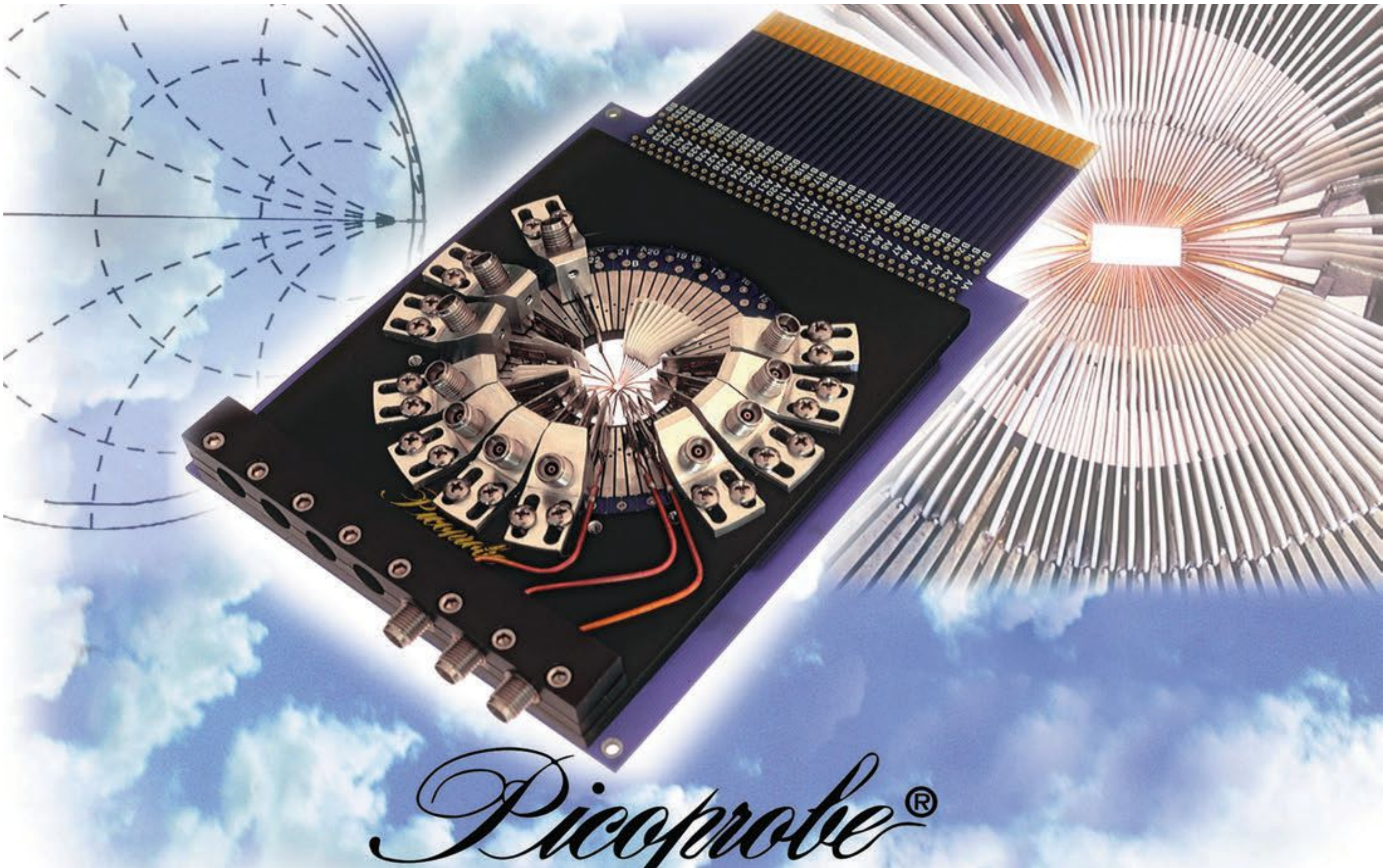

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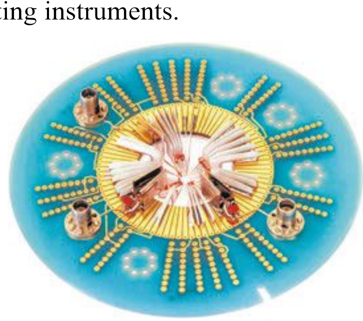

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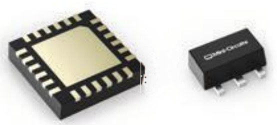

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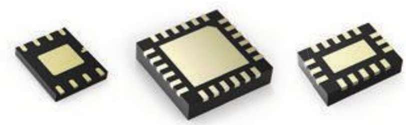

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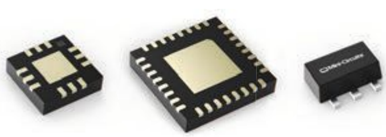

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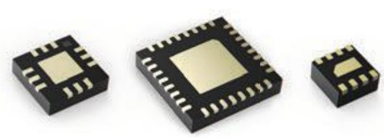

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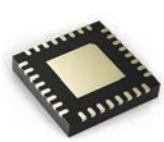

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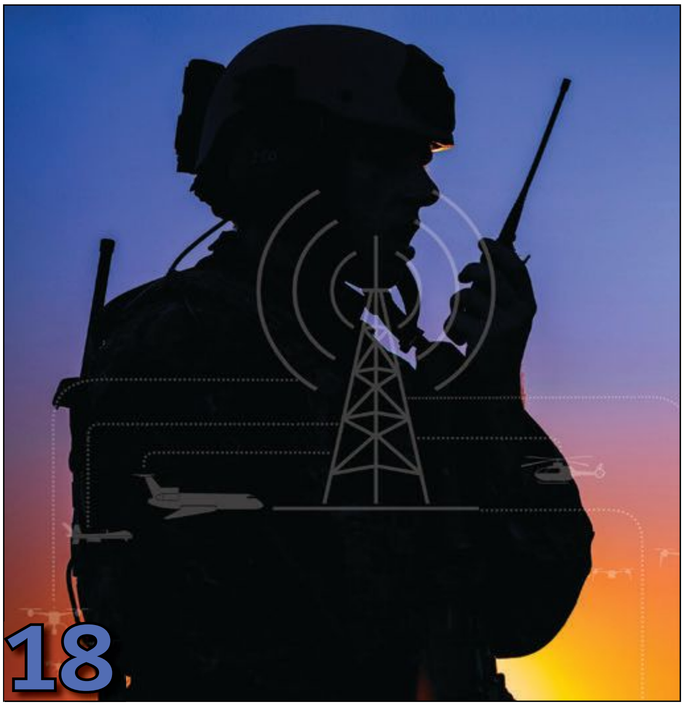

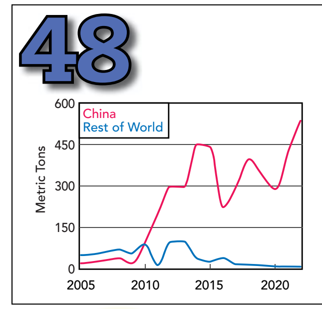

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Xiaoxi Cui, Haihui Yu, Jiqun Jiang, Fenglong Hao, Changjian Tao and Chuan Jin, First Research Institute of The Ministry of Public Security, Beijing, China

Shiyong Li and Houjun Sun, Beijing Institute of Technology, Beijing, China

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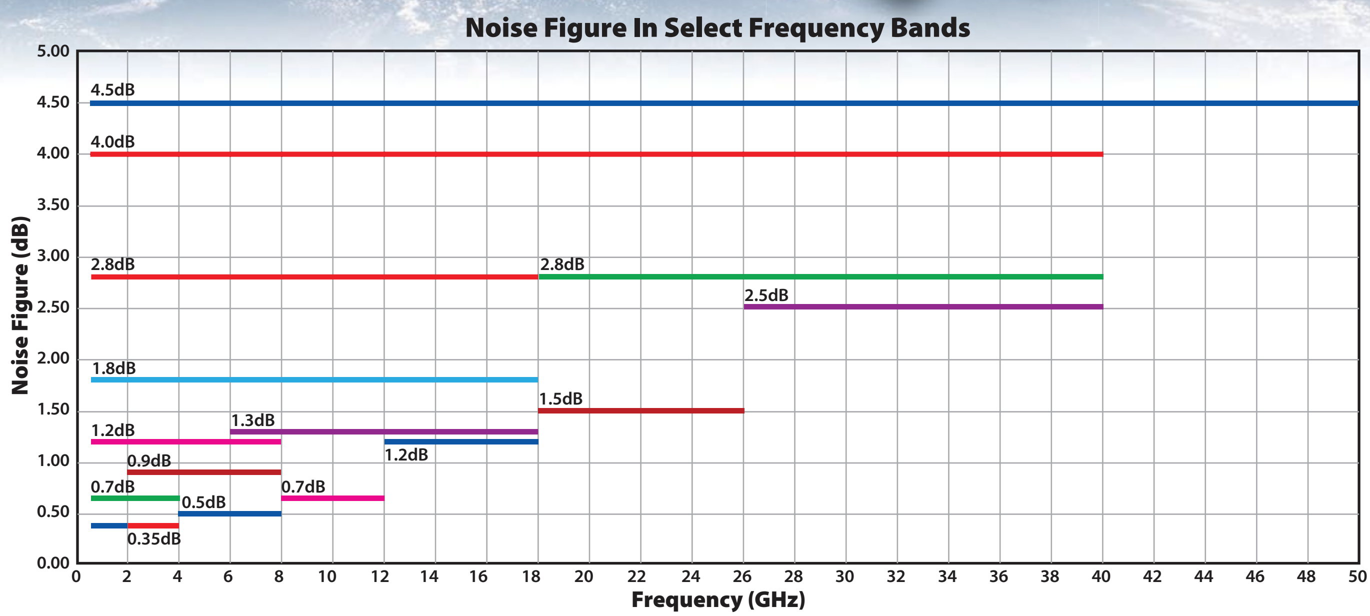
Noise Figure In Select Frequency Bands
Noise Figure (dB)
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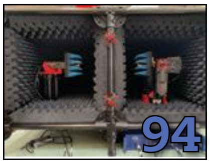

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Christoph Kienmayer, Managing Director and Founder of **PIDSO**, talks about the heritage and business model of PIDSO, along with the company's product portfolio and where PIDSO is focusing its next-generation development efforts.

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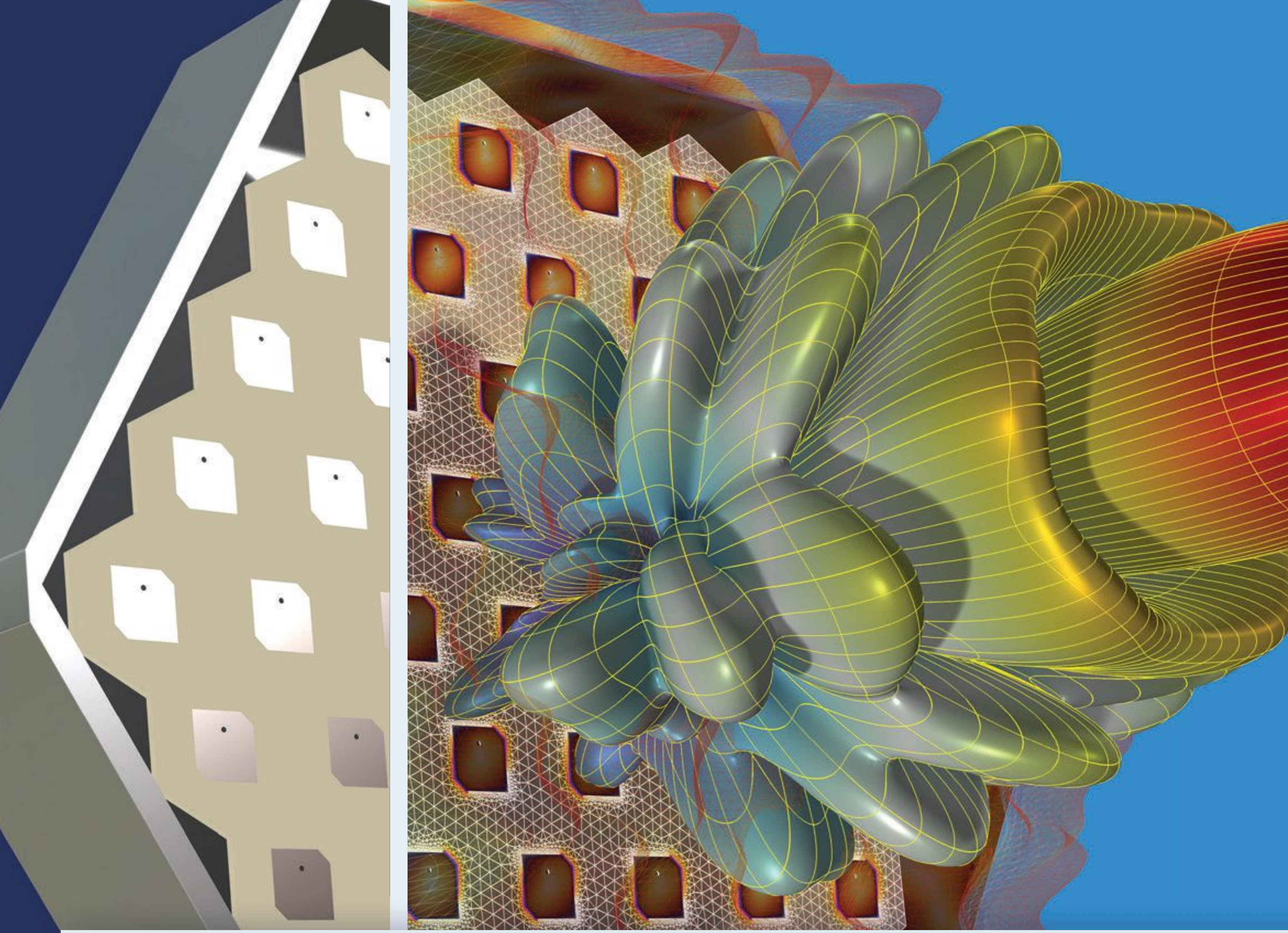

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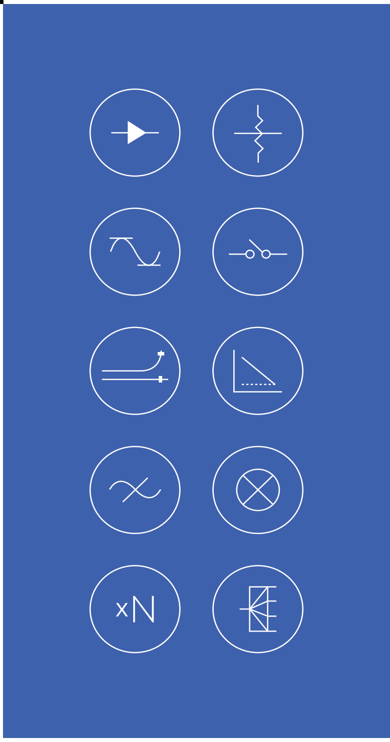

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Comparing SDRs for Aerospace and Defense Electronics

Kaue Morcelles and Brandon Malatest
Per Vices

New aerospace and defense systems must implement high performance radio equipment to communicate, operate and keep their assets safe. The battlefield is dynamic, so being able to adapt easily is extremely important. Software-defined radios (SDRs) are a type of RF transceiver that implements most of the radio operations through software. These radios can be reprogrammed to comply with different requirements and modify functionality. These devices are extremely flexible and versatile to help defense organizations maintain superiority. High performance RF devices are an integral part of aerospace and defense systems. For instance, radars are useful to detect and track physical targets in all domains, electronic warfare (EW) systems are critical tools to disrupt enemy communications and networks and spectrum monitoring and recording systems can intercept and analyze threats present in the electromagnetic spectrum. RF systems are also crucial for satellite communications, surveillance and navigation.

This article will compare high performance commercial off-the-shelf (COTS) SDRs for aerospace and defense applications, investigating their performance specifications in detail. SDRs are extremely popular in the aerospace and defense industry, as they provide flexibility, accuracy and robustness in a small and modular footprint. The article will cover the main requirements for different aerospace and defense applications, including radars, spectrum monitoring systems, EW devices, satellite communications, surveillance and navigation. It will also compare COTS SDR models from three suppliers: the Cyan model from Per Vices, the USRP X410 from National Instruments (NI) and the HTLw SDR from Herrick Labs. The analysis will investigate important specifications like frequency range, bandwidth, sampling rate, dynamic range, modulation schemes and signal-to-noise ratio (SNR).

WHAT IS AN SDR?

SDRs are an RF device that implements most of its radio functions in the digital domain. They can be easily modified to work with a wide range of applications through simple software updates, without requiring hardware changes. The core of an SDR is the radio front-end (RFE) and the digital backend, which communicate with each other through analog-to-digital (ADC) converters and digital-to-analog (DAC) converters. The RFE implements all the analog functions required for receive (Rx) and transmit (Tx) operations, including filtering, amplifying and mixing. The RFE specifications limit SDR performance, so the highest bandwidth SDRs in the market implement RFEs with DC to 18 GHz tuning ranges, which may be upgradable to 40 GHz. These RFEs typically have 3 GHz of instantaneous bandwidth, while also providing excellent SNR and dynamic range. MIMO SDRs are state-of-the-art in terms of RF functionality, implementing RFEs with multiple Rx and Tx channels that can work in parallel through independent ADC/DAC channels. The digital backend of an SDR typically contains a field-programmable gate array (FPGA) with onboard digital-signal processing capabilities for implementation of the basic RF operations. These operations include modulation and demodulation, up- and down-converting, data packaging and filtering. They also extend to complex radio protocols, smart algorithms and high throughput host communication interfaces. High performance SDRs also provide powerful host interfaces using qSFP+ ports for optical Ethernet links that can reach 400 Gbps performance, typically with four 100 Gbps lanes. ***Figure 1*** provides a high level overview of SDR boards.

SDR USAGE IN DIFFERENT APPLICATIONS

Radar systems are important in both aerospace and military defense applications. Radars come in many varieties: Doppler radars, synthetic aperture radars, ground-penetrating radars, pulse radars and continuous-wave radars. These systems are used for a variety of functions, like tracking, target identification, surveillance and imaging, so the RF transceiver must be able to adapt to a variety of conditions

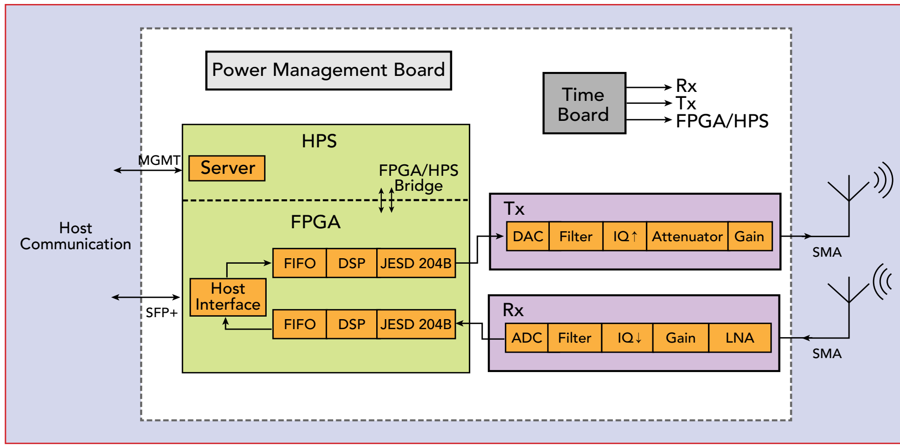

Fig. 1 **High-level view of an SDR.**

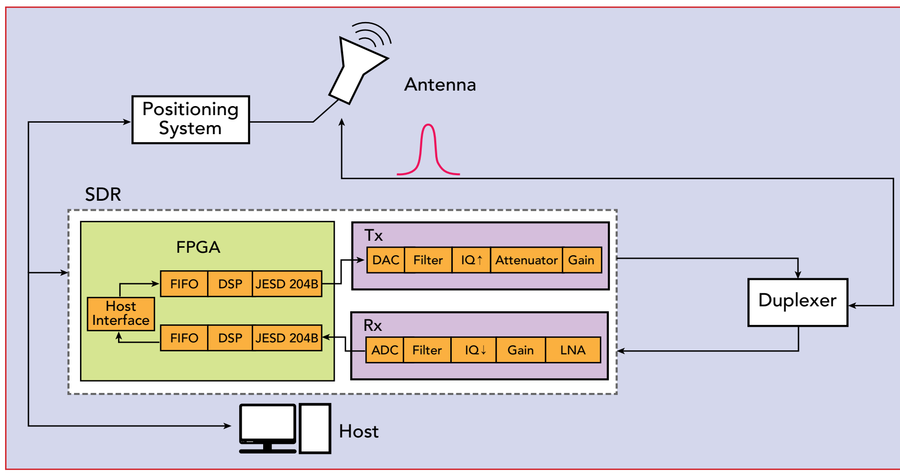

Fig. 2 **Representative radar block diagram with an SDR.**

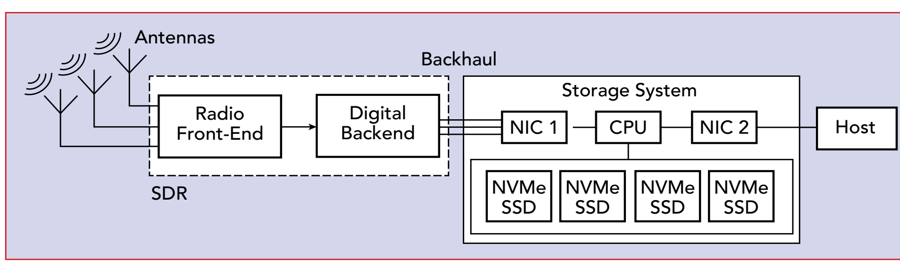

Fig. 3 **SDR integrated into a spectrum monitoring and recording solution.**

and specifications. One of the main advantages of SDRs in radars is the flexibility to configure the signal processing chain to adapt to changing operational requirements. This allows the system to adapt to jamming signals, challenging weather conditions and clutter. Furthermore, MIMO SDRs enable radar systems to process multiple channels in real-time, which is useful for multiple-antenna applications where different frequencies can be used to simultaneously cover different ranges or phased arrays can be used to focus the sensitivity using beam steering techniques. Finally, because these transceivers are modular, they can fit a variety of size, weight and power (SWaP) requirements, from large ground stations to small onboard drone units. ***Figure 2*** illustrates a high level block diagram of a radar system with SDRs in the Rx/Tx chains for signal processing.

Spectrum monitoring and recording is another important RF application in aerospace and defense. This application uses powerful radio transceivers to detect and analyze the frequency content of the electromagnetic environment. SDRs are well-suited for spectrum monitoring systems since the RFE circuits have wide tuning ranges, high instantaneous bandwidth and several parallel channels with a low noise figure and high dynamic range, along with a high level of flexibility and reconfigurability. Spectrum monitoring systems using SDRs can provide real-time spectrum awareness, wideband signal monitoring and precise signal identification. This allows these systems to rapidly improve the spectrum sensitivity depending on the conditions of the RF environment. These systems use the flexibility and adaptability of the digital backend to monitor a wide range of frequencies and bandwidths simultaneously. This increases the sensitivity and selectivity of detecting and recording signals based on a programmed threshold that can be easily and remotely modified with software. MIMO SDRs can also significantly improve the spectrum coverage since each RF chain can cover a portion of the spectrum, independently, with a pre-defined gain/attenuation profile to optimize performance. High performance SDRs can provide high throughput backhaul for the host interface, allowing better integration with powerful storage solutions, along with incorporating network interface cards and NVMe drives to prevent data loss while optimizing consumption. ***Figure 3*** shows a high level block diagram of a spectrum monitoring architecture and an SDR in the receive chain for signal processing and recording. In these systems, SDRs digitize and process the incoming signals, with sophisticated algorithms running on the backend for signal analysis and classification.

EW is an important part of any modern military strategy and SDRs have become an essential tool for many EW applications, especially the ones involving aircraft and satellite operations. In these applications, SDRs perform electronic support measures (ESMs) to intercept and analyze electromagnetic signals coming from enemy radar and spectrum monitoring systems in real-time. These transceivers can also be used in electronic countermeasure (ECM) systems to jam or deceive enemy systems and in electronic attack (EA) systems to disrupt or destroy enemy devices. MIMO SDRs

can augment EW transceiver capabilities by implementing ESM, ECM and EA operations simultaneously, using the dynamically controlled gain of the Tx and Rx chains to optimize signal detection and generation. SDR programmability enables rapid development and deployment of new EW capabilities as the threat landscape evolves, without the need for physical intervention or software replacement. The digital backend unit can rapidly adapt the modulation/demodulation scheme and communication protocol for advanced eavesdropping and anti-jamming techniques like frequency hopping. ***Figure 4*** shows a block diagram of an EW transceiver that uses an SDR and beam steering to minimize the effects of jamming signals and adaptatively improve tracking sensitivity.

KEY AEROSPACE AND DEFENSE SDR SPECIFICATIONS

Selecting SDRs for aerospace and defense applications typically involves analyzing four critical performance indicators: tuning range, channel count, sampling bandwidth and digital backhaul. By analyzing these parameters, the engineer/designer can evaluate the device utility for a specific application, as well as how to optimize any possible limitations. The tuning range of an SDR establishes the frequency band where the RFE can receive and transmit signals with the proper gain and without major artifacts. In EW and spectrum monitoring applications, a wide tuning range is essential to quickly sweep between frequencies and optimize the probability of signal detection and monitoring. SDR-based radars can use their wide tuning range to direct different frequencies to multiple antennas to cover different requirements.

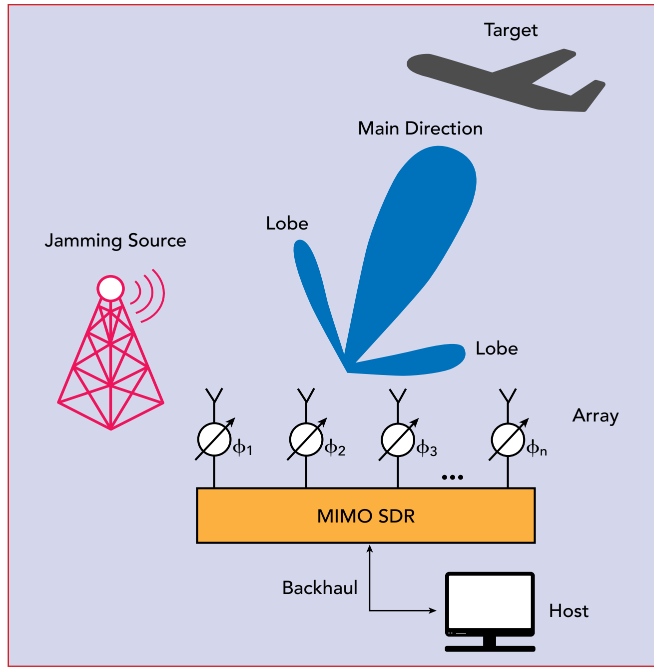

Fig. 4 **SDR and phased-array block diagram for EW applications.**

The channel count is also extremely important in aerospace and defense applications. Devices often need to acquire signals from completely different sources simultaneously, use phased array antenna systems for beamforming and perform multiple EW tasks in parallel as part of an "all-in-one" solution. In these cases, the MIMO SDR channels must be controlled, processed and activated independently to reduce latency and improve phase and frequency stability.

Sampling bandwidth is another frequency-related performance metric. The parameter defines the frequency range at which an SDR can sample accurately. This characteristic is essential to ensure sufficient frequency resolution to properly differentiate between harmonics for spectrum monitoring applications that capture and process high frequency, wide bandwidth signals in multiple channels.

Digital backhaul refers to the ability of an SDR to transmit and receive data over a digital interface that may be connected to a host or network. High speed digital backhaul is crucial for EW and spectrum monitoring applications. That connection

enables rapid processing and analysis of large amounts of data with minimum loss of information.

It is important to note that other parameters may be more critical than these, depending on the exact device requirements. These parameters may include SWaP specifications, FPGA resources, FPGA accessibility, form factor and modularity level. Although some of these specifications are beyond the scope of the article, each SDR listed has benefits and drawbacks in these areas.

COMPARING SDRS

Having reviewed the basics of SDRs, the likely applications of these transceivers in aerospace and defense applications and important parameters to consider when selecting and designing these systems, it is time to compare the SDR models. This section compares SDRs from Per Vices, NI and Herrick Labs.

The Cyan SDR from Per Vices is a COTS transceiver targeting spectrum monitoring, radar and EW applications. This device offers a frequency tuning range from near DC to 18 GHz, making it an appropriate choice for high frequency applications. With a channel count accommodating up to 16 independent radio chains, this SDR can perform several different functions in the same device. This makes the device useful in applications like EW and spectrum monitoring, where multiple operations must be performed simultaneously and phased array radar systems with multiple antennas that require good phase and frequency coherence. The channel count, combined with 3 GHz instantaneous bandwidth and 24-bit/32-bit resolution per channel, increases the spectrum coverage capabilities of this device. Each channel can be assigned to a different portion of the spectrum with optimized gain and power thresholds.

The backhaul architecture of this transceiver allows up to 4 × 40 Gbps, upgradable to 4 × 100 Gbps in the high bandwidth version, channels over optical qSFP+ links, enabling high data throughput and very low latency backhaul. This is a bottleneck for many SDR models and this feature satisfies a need in high performance recording solutions. The trade-off with these performance capabilities is that the Cyan SDR does not provide the best SWaP solution. ***Figure 5*** shows the CYAN SDR.

The HTLw SDR, from Herrick Labs, can operate with a tuning range from 20 MHz to 18 GHz while providing an instantaneous bandwidth of about 1 GHz per channel. This enables the device to be used in a variety of high frequency applications, including spectrum monitoring, radars and complex EW systems. With four Tx and four Rx channels, it has a lower channel count than Cyan, but the advantage is a smaller form factor. One of the most significant benefits of the HTLw is the low phase noise per channel, combined with high bandwidth, making it suitable for many systems. It also features a powerful FPGA with onboard ARM9 cores and NEON coprocessors. The FPGA is capable of handling new, complex waveforms and heavy parallel signal processing in multiple channels. The HTLw provides two 10 GbE Ethernet ports with a compact design that makes it suitable for low SWaP onboard applications. This SDR is shown in ***Figure 6***.

The final model is the NI USRP X410. This product is part of their universal software radio peripheral (USRP) line of products. This family of SDRs is open-source, allowing designers to create customized solutions. In this device, the digital backend is based on the Xilinx Zynq Ultrascale+ ZU28DR RFSoC, featuring a 12-bit resolution DAC and a 14-bit ADC that provides good computational resolution. The USRP RFE tuning range is 1 MHz to nearly 8 GHz, with up to 400 MHz of instantaneous bandwidth per channel. This is sufficient for applications including real-time signal process-

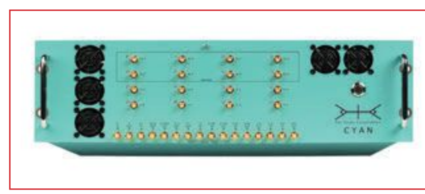

Fig. 5 Cyan SDR from Per Vices.[1]

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ing and rapid prototyping, but insufficient for complex spectrum monitoring solutions. The SWaP characteristics of this transceiver are its differentiator. This device houses four Tx and four Rx channels in a half-wide RU form factor. This makes for a high channel density, but the total channel count is significantly lower than some of its competitors. This makes the X410 an attractive option for portable, onboard and battery-powered applications, thanks to its relatively low power consumption and small form factor. The backhaul has two QSFP28 ports going up to 10/100 GbE and a high speed data communication host interface that is not compromised by the small form factor. Although the USRP X410 is limited in terms of channel count and bandwidth when compared to the other two models, its flexibility and compatibility with popular software platforms, like LabVIEW and MATLAB, make this transceiver an excellent choice for engineers and researchers looking to prototype and test novel architectures for the aerospace industry. The USRP X410 is shown in ***Figure 7***.

When selecting the most appropriate SDR for a particular application, several factors need to be considered. The number of channels, bandwidth, form factor and backhaul requirements all play a vital role in determining which SDR is best suited for a specific application. For instance, if a user requires a high number of channels, along with high bandwidth operation and high throughput backhaul, the Per Vices Cyan would be an excellent choice. However, it may not be the most suitable option for applications with strict SWaP requirements. On the other hand, the Herrick Labs HTLw provides high frequency performance with a small form factor and high spurious-free dynamic range, but at the cost of a lower channel count. Additionally, the NI USRP X410 is a budget-friendly option that offers great value for fast prototyping and non-critical applications, but it provides lower overall performance compared to the other two models. Ultimately, it is essential to understand the performance parameters and their application-specific benefits when selecting an SDR for a particular use case. A comparison of the key performance metrics of the referenced SDRs is shown in ***Table 1***.

CONCLUSION

SDRs are becoming increasingly important in the aerospace and defense industries due to their abil-

Fig. 6 The HTLw SDR from Herrick Labs.[2]

Fig. 7 The USRP X410 from National Instruments.[3]

TABLE 1
SDR COMPARISON

SDR	Core	Tuning Range	Resolution	SFDR (dB)	Channel Count	Bandwidth (per channel)	Digital Backhaul	Form Factor
Per Vices Cyan	Intel Stratix 10 SoC/ARM Cortex-A53 MPCore	Near DC to 18 GHz	32-bit	60	16 Tx/Rx	3 GHz	4x 40/100 Gbps qSFP+	19 in. 3U 482.6 x 402.0 x 133.0 mm 6.2 kg
NI USRP X410	Xilinx Zynq Ultrascale+ ZU28DR RFSoC/ Quad-core ARM Cortex-A53	1 MHz to 8 GHz	12-bit ADC 14-bit DAC	NA	4x Tx 4x Rx	400 MHz	2x 10/100 GbE qSFP28	½ RU 28.5 x 22.2 x 4.4 cm 2.5 kg
Herrick Labs HTLw	Non-specified FPGA with ARM9 Cores/ NEON Coprocessors	20 MHz to 18 GHz	NA	80	4x Tx 4x Rx	1 GHz	2x 10 GbE Ethernet	NA

ity to adapt to different use cases and protocols. Key specifications for SDRs in these markets include tuning range, channel count, sampling bandwidth and digital backhaul. The Per Vices Cyan Model, the NI USRP X410 and the Herrick Labs HTLw are examples of currently available, high performance SDRs with their own unique set of specifications and benefits. Overall, SDRs play a critical role in this industry, so the selection of the appropriate transceiver for a particular use case greatly impacts the performance and success of any mission and should not be taken for granted. ■

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2. Herrick Labs, HTL Products, Web: www.herricktechlabs.com/htl-products-and-solutions/htl-core-radios.
3. NI, Ettus USRP X410, Web: www.ni.com/pt-pt/support/model.ettus-usrp-x410.html.

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INVITED PAPER

Large Cash Reserves Are Fueling RF and Microwave M&A

Kyle Morgan
Sperry, Mitchell & Company, New York, N.Y.

The signals are strong and clear; in recent years, the amount of cash directed to acquisitions in the RF and microwave space has soared, leaving potential sellers with a host of options. A decade ago, owners of RF and microwave companies faced a lack of quality acquirers, as investors' lack of industry expertise made it difficult, if not impossible, for institutional funds to finance acquisitions in the space. Today, the story unfolds quite differently. The acceleration of wireless communication, the demand for high-tech defense systems and the growing cross-functionality of radar have made the RF and microwave space particularly attractive. Players are now far more knowledgeable and have a much larger appetite to take advantage of long-term tailwinds.

As a result, the market has been flooded by potential acquirers, including many investment firms. These groups, typically private equity (PE) funds, are backed by large amounts of capital specifically meant for acquisitions. Even more importantly, their funds must be spent within a predefined time period, typically five years after being raised, meaning they are eager to make investments when quality opportunities are available in the market.

WHO ARE ACQUIRERS TARGETING?

Increased competition within the industry has presented obstacles to organic growth and acquirers are looking to satisfy their desire to scale and solidify their competitive advantage through strategic consolidation. Consequently, smaller companies have become more enticing to acquirers than in past years. Investors have zeroed in on several common characteristics, including:

- Proprietary technologies
- Unique capabilities
- High performance, high-reliability products
- Robust, repeat customer base
- Strong in-house technical talent.

By targeting a variety of smaller companies with niche market positions, consolidators can develop a cohesive portfolio of significantly more value as a collective unit than as the sum of its parts.

SO, WHY NOW?

There are several reasons for the build-up of acquisitions in the RF and microwave space. Primarily, there is a historically significant surplus of cash available to be spent by both corporate acquirers and investment firms. This surplus can be attributed to large amounts of PE fundraising in the past few years, as well as a recent lack of quality investment opportunities where cash can be deployed. Additionally, this supply of cash is spread across an array of acquirers with interest and experience in the RF and microwave industry. This has created a large imbalance between the number of acquirers seeking to do deals within the space and the number of quality companies entertaining a sale process. The good news is that this mismatch has afforded sellers the opportunity to engage in a variety of discrete options with buyers who are willing and able to pay a premium price.

HOW DO ACQUIRERS THINK ABOUT VALUATION?

There is no "one size fits all" approach to valuation and it is commonplace for different acquirers to ascribe different values to the same company. Synergistic expectations or the anticipated benefits that a transaction is expected to unleash in combination are a clear

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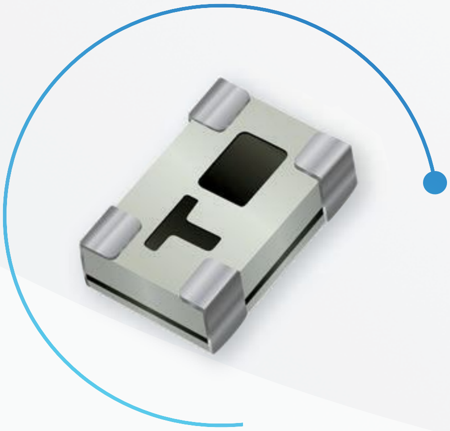
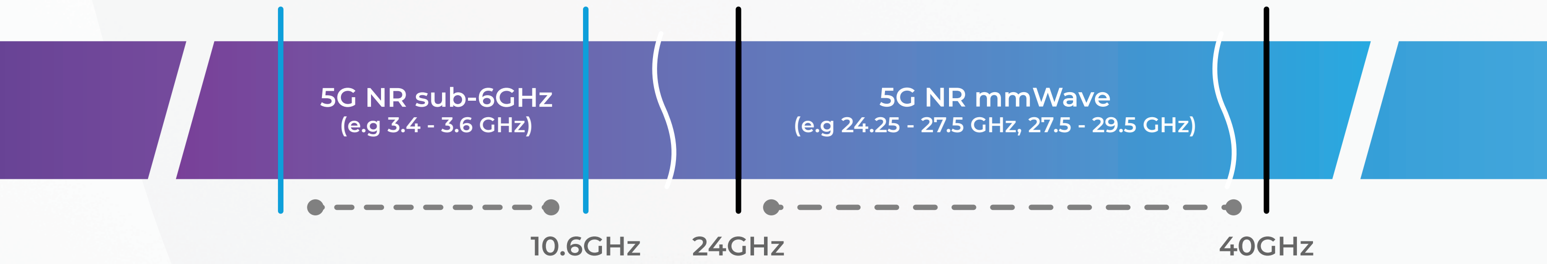


5G technology (3.1-10.6 GHz , 24 - 40 GHz) uses a very low energy level for short-range, high-bandwidth communications over a large portion of the radio spectrum.

Most recent applications target sensor data collection, precision locating and tracking applications and vehicle to everything communication.

During the coming years, the number of wireless sensor and communication systems will increase significantly, due to the expected low costs of these systems and their technical advantages.



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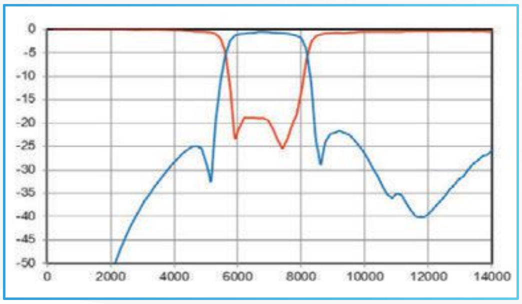

1206 Size, Central Frequency: 6.67 GHz
Passband: 1.55 GHz

Applications

Military | Base Stations | Test Equipment | Handheld Radios | Consumer | Active Antenna Systems | Automotive | Emergency Services driver of this phenomenon. This is the additive mergers and acquisitions (M&A) concept that 1 + 1 can equal 3. Despite these variations, the one universal trait that both financial and strategic buyers focus on when thinking about valuation is the bottom-line earnings that a company generates.

The standard practice for valuing a business is to apply a multiple to its annual earnings. The magnitude of the multiple depends largely on the buyer's distinct motivations and business outlook for the sale target. Sellers that check the box of more target characteristics will achieve a higher multiple of earnings. Conversely, businesses that lack desired target qualities will be valued at a lower multiple of earnings.

WHAT IS THE TIME FRAME?

On the individual buyer scale, acquisitions come in waves. For PE firms, a long-going strategy to drive value has been the "buy-and-build" approach, in which a PE firm acquires an initial platform with the intention of further acquiring and merging companies in a fragmented market. Recent examples of buy-and-build consolidators have included:

- Abracon (owned by Genstar Capital)
- Infinite Electronics (owned by Warburg Pincus)
- Maury Microwave (owned by Artemis Capital Partners)
- Micross Components (owned by Apollo Global Management)
- Quantic Electronics (owned by Arcline Investment Management).

More broadly speaking, the time horizon for this acquisitive environment is difficult to predict. If market growth slows or investors' access to capital dries up, the demand for acquisitions may decline. However, consolidators have exhibited a clear appetite for small- and medium-sized companies in the RF and microwave space. It is likely that the consolidators will continue to have this appetite, provided that the terms and benefits of these acquisitions remain to their advantage. ■

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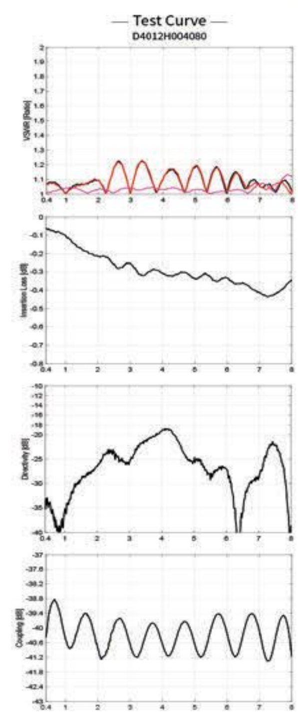
0.4-8GHz Directional Coupler								
D3002H004080	120	30	1.3	1.3	0.8	30±1.0	±0.8	18
D4002H004080	120	40	1.3	1.3	0.8	40±1.0	±0.8	18
D3005H004080	250	30	1.4	1.4	0.7	30±0.9	±1.3	14
D4005H004080	250	40	1.4	1.4	0.7	40±1.0	±1.4	14
D3008H004080	400	30	1.4	1.4	0.7	30±0.9	±1.3	14
D4008H004080	400	40	1.4	1.4	0.7	40±1.0	±1.4	14
D3012H004080	600	30	1.4	1.4	0.7	30±0.9	±1.3	14
D4012H004080	600	40	1.4	1.4	0.7	40±1.0	±1.4	14
0.4-8GHz Dual-Directional Coupler								
D3002HB004080	120	30	1.3	1.3	0.8	30±1.0	±1.0	18
D4002HB004080	120	40	1.3	1.3	0.8	40±1.0	±1.0	18
D3005HB004080	250	30	1.4	1.4	0.7	30±0.9	±1.5	14
D4005HB004080	250	40	1.4	1.4	0.7	40±1.0	±1.6	14
D3008HB004080	400	30	1.4	1.4	0.7	30±0.9	±1.5	14
D4008HB004080	400	40	1.4	1.4	0.7	40±1.0	±1.6	14
D3012HB004080	600	30	1.4	1.4	0.7	30±0.9	±1.5	14
D4012HB004080	600	40	1.4	1.4	0.7	40±1.0	±1.6	14

*Theoretical I.L. Included



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Advanced Communications Out of the Lab and Into the Field

Lockheed Martin demonstrated its Hybrid 5G-Tactical Mesh Network live in a multi-domain environment. This is a significant step toward ensuring the Department of Defense has seamless access to critical information. Working with leading commercial technology companies, Lockheed Martin proved the integration of existing technologies with enhanced capabilities that provide superior advanced communications operations and management tools for military applications.

The 5G.MIL® Unified Network Solutions (UNS) were successfully tested across numerous mission simulations to establish stability and suitability for use in Joint All-Domain Operations and Combined Joint All-Domain Command and Control. The resilient 5G.MIL UNS tactical mesh network and Lockheed Martin's AI Factory machine learning operations platform were critical to successfully deploying these AI-based capabilities.

> 5G.MIL Unified Network Solutions demonstrates secure, resilient hybrid networking.

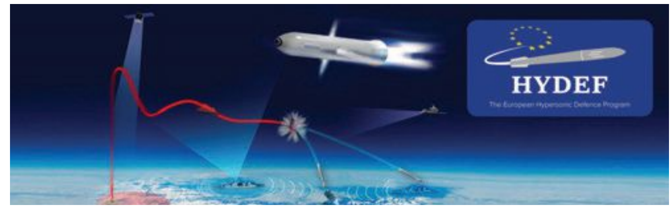
In this demonstration, Lockheed Martin's 5G.MIL UNS performed as a tactical and commercial multi-node hybrid network for land, air and space domains — demonstrating system capabilities, performance and operations for customers in a field setting — and achieving Technology Readiness Level 6+, meaning it is a fully functional prototype model. The deployed hybrid network included five hybrid base stations with 5G, tactical datalinks and space backhaul. Fifteen individual capabilities were demonstrated across mission scenarios, covering interoperability, resilience, security and operations. This exercise provided an opportunity to stress test the maturity and resilience of the independent hybrid network in a mission-relevant scenario.

Lockheed Martin's solutions deploy, orchestrate and manage enhanced commercially available technologies from multiple embedded collaborators, including:

Lessons learned from this field demonstration are already being incorporated into Lockheed Martin 5G.MIL UNS. The company will continue to work with commercial collaborators toward an Initial Operating Capability in 2024.

HYDEF Project Reaches Next Milestone

On October 31, 2023, the contract between Organisation Conjointe de Coopération en matière d'Armement (OCCAR) and Spanish



HYDEF (Source: Diehl Defence)

Missile Systems (SMS) for the Hypersonic Defence Interceptor Study (HYDEF) project was signed in Bonn, Germany.

As the first European program for defense against hypersonic threats, the European HYDEF project of the consortium around SMS (Escribano Mechanical & Engineering, GMV and SENER AEROSPACIAL, among others) from Spain and Diehl Defence from Germany was able to clearly position itself by signing the contract with OCCAR. This marks the official start of the project. The consortium consists of 13 companies from seven European nations.

Diehl Defence CEO Helmut Rauch congratulated the project team and announced, "This is an important milestone for the HYDEF project. The realization of tomorrow's air defense, specifically against hypersonic threats, can now begin in Europe."

SMS is responsible for project management within the HYDEF project. Diehl Defence heads the technical implementation, from the development of the overall system to the interceptor itself. In the future, the overall system will be able to detect and intercept hypersonic cruise missiles as well as highly agile hypersonic glide vehicles. All this will be realized through the networking of various, partly space-based sensors and the interceptor system, which will be deployed on the basis of existing NATO BMD command and control systems wherever possible. The consortium is optimally qualified to solve this highly complex and multidimensional task of system interconnection.

HYDEF is closely linked to the PESCO EU project Timely Warning and Interception with Space-based TheatER surveillance (TWISTER) and deals with the development of an overall endo-atmospheric interceptor concept for air defense. This project is being funded with 100 million euros.

UK Research into Mine Detecting Drones Could Change Land Warfare

Scientists and engineers at the Defence Science and Technology Laboratory (Dstl) are conducting crucial research into the new drone technology, which would see mined areas cleared faster and more safely, ramping up protection for armed forces personnel.

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

Maintaining freedom of movement and mobility at pace for the armed forces is vital for safety and mission effectiveness and this is significantly reduced by land mines, explosives or buried munitions.

The Dstl team, along with industry partners, participated in trials with NATO allies in Spain and at the Suffield Research Centre in Canada. Advances in uncrewed aerial vehicles (UAVs) and low size, weight and power sensing have led to the development of innovative concepts for explosive threat detection by combining these technologies and systems. Minister for Defence Procurement James Cartlidge MP said, "We've all seen the threat to safety and military advancement that mines can still pose.

The U.K. and our NATO allies are spearheading research into this technology, which has the potential to not only enhance protection for our Service Personnel, but also speed up battlefield progress."

Defence Science and Technology Laboratory Chief Delivery Officer Matt Chinn said, "Converging the latest drone and sensing technologies could give us the ability to detect and destroy deadly mines and explosives without putting lives at risk."

He continued, "It could also give us the ability to clear mined areas better, quicker and cheaper — allowing military operations or humanitarian missions to proceed."

Researching technologies such as mine-detecting drones has the potential to change the approach to land warfare by significantly reducing the threat and effectiveness of ground mines.

> Goal to detect and destroy deadly mines and explosives without putting lives at risk.

Technologies that can be used to detect these threats in advance can be vital in determining the next course of action on the battlefield.

The two-week NATO trials aimed to give international and academic organizations the opportunity to showcase their UAV-mounted sensor concepts and to share ideas, knowledge and solutions.

The resulting experiments demonstrated a range of modified, novel and bespoke sensing technologies. The U.K. system performed well under the trials, and the intention is to use the results of the assessments to prioritize the next stages of research and development. As part of an overarching research project commissioned by the Ministry of Defense's Chief Scientific Advisor, it will be developed over the next decade into front-line command-funded equipment programs, such as the Ground Area Reconnaissance and Assurance project.

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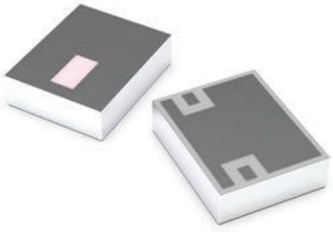

Model Number	Passband (MHz)	Stopband F3 (MHz)	Rejection @ F3 (dB)	Stopband F4 (MHz)	Rejection @ F4 (dB)
BFCQ-2702+	22000-31000	100-17100	42	35700-48000	43
BFCQ-2872+	27500-30000	100-22200	32	35300-55000	28.4
BFCQ-1932+	17700-21000	DC-14600	30	25600-40000	40
BFCQ-1982+	17700-20200	100-14500	55	24000-40000	45
BFCQ-1162+	10700-12700	100-8800	40	15100-27000	38

Cliff Drubin, Associate Technical Editor

Evolving Devices for 5G Adoption

The landscape of 5G devices is evolving rapidly to meet the diverse needs of various use cases, ranging from smartphones to specialized IoT devices and emerging battery-less ambient IoT devices. 5G Americas has introduced a briefing paper titled "Evolving Devices for 5G Adoption," which examines the evolution of 5G devices, shedding light on the optimization and adaptation of 5G technologies that cater to a wide array of use cases.

Chris Pearson, president of 5G Americas, shared his perspective, "The evolution of 5G devices signifies a dynamic shift in connectivity, transforming industries and empowering individuals. From the power of smartphones to the promise of ambient IoT, this 5G Americas' briefing paper unveils the future diversity of 5G devices." Key topics covered include:

- Device Characteristics: As 5G reshapes global communications, device features remain crucial. Characteristics like mobility, bandwidth, size, accessibility, cost, security, coverage, battery life and radio access technology influence the design and functionality of 5G devices for various applications.
- Device Landscape: Beyond smartphones, the device ecosystem is rapidly growing to include augmented reality glasses, voice-enabled devices and specialized IoT technologies. These developments are transforming industries, improving communication and enabling remote healthcare monitoring.
- Reduced Capability Devices: Initially, 5G New Radio technology focused on enhanced Mobile Broadband (eMBB) applications. 3GPP later introduced Reduced Capability (RedCap) specifications in Release 17 to cater to low-throughput, cost-effective and energy-efficient use cases. These devices offer a balanced solution for data rate, latency and battery life.
- Ambient IoT: Ambient IoT devices operate solely on energy harvested from their environment, eliminating the need for batteries. Characterized by their small form, low cost and ultra-low power consumption, they find uses in various sectors, such as inventory management and environmental sensing.

Wireless Infrastructure Drives RF Power Semiconductor Markets to Over $1B

The potential of E-Band to fulfill the backhaul capacity needs of most 5G deployments beyond 2030 is among the key topics of the Microwave Outlook 2023 report from Ericsson. The tenth edition of this industry report from Ericsson also looks at the latest innovations in antenna designs and how AI and automation can lower operational costs of transport networks.

E-Band spectrum (71 to 86 GHz) can meet the backhaul capacity needs of most 5G sites up to 2030 and beyond, being already open for deployment in countries where 90 percent of the world's population lives, according to the report. The projection is supported by a simulation of backhaul networks from three European cities with different densities of E-Band links.

The report also shows the trend of a gradual increase in the share of fiber-connected installed sites vis-à-vis those connected with microwave solutions, reaching a 50/50 split by 2030. Microwave solutions will be the main connectivity option where fiber is unavailable, and the preferred solution in rural areas where fiber investments can be challenging.

Innovation is in focus with the report looking at how new antenna designs enable better use of required spectrum in dense networks, lower spectrum costs and improve performance. For example, 0.9 m sway compensation antennas provide 80 percent longer hops than 0.3 m regular antennas. The value of other antenna innovations, such as multi-band and water-repellent radomes is also highlighted.

A case from Greenland illustrates how long haul can be a perfect solution for providing residents in faraway locations with easy access to the high speed mobile communications integral to modern life. A local service provider has been using a microwave network to serve the connectivity needs of settlements along the west coast over a distance of 2,134 km (corresponding to the flight distance between Brussels and Athens). This network is now being upgraded and expanded to cater to the higher capacities of 5G.

Another case in the report describes how operational costs for managing a microwave network can be significantly reduced by applying AI-based network automation. The benefits include less time spent on troubleshooting, a reduction of site visits by at least 40 percent, and better overall prediction and planning.

Microwave Outlook is a technology report focusing on microwave backhaul networks, with in-depth articles on current and emerging trends and developments in different areas that can be of interest for communications service providers who are using, or considering the use, of microwave backhaul in their network.

Autonomous Shipping to Get Satellite Connectivity Breakthrough

Remote-control technology and service provider for unmanned and crew-reduced shipping SEAFAR is integrating neXat, a satellite communications services platform, into its remote ship navigation solution for the short sea shipping (SSS) industry.

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The two-year project is co-funded with the European Space Agency and is being tested at sea together with a Belgian SSS company that has lines sailing in the Baltic Sea and from Spain to the U.K. and Antwerp, Belgium. The initial scope of the project is to integrate 4G and 5G with satellite communications into a ubiquitous, fully managed connectivity service allowing the critical operations of autonomous shipping.

neXat's platform will ensure that connectivity coverage is not lost by automatically and quickly switching from 4G or 5G to satellite as required. This means that real-time data, including camera feeds and performance monitoring and navigational information, is continuously shared and ensures increased situational awareness in SEAFAR's Remote Operations Center. The unique neXat monitoring and management functionalities will also be integrated into the SEAFAR dashboards to provide captains with all the monitoring and management information necessary to ensure the required solution's reliability.

The solution, called SeaNext, will also monitor all available networks, providing a connectivity "heatmap,' allowing ship owners and service providers to plan ahead for coverage black spots in remote locations.

The connection between remote operations center and the vessel uses 4G or 5G and in the case of the unavailability of a terrestrial network, satellite communications are used and provided by neXat. 5G is used for higher bandwidths to send sensor data.

> Provides ubiquitous coverage to ensure seamless communications, situational awareness and safety.

The solution will provide camera streams and information about engine sounds and monitor performance, position, heading and speed of the vessel, as well as those of surrounding vessels, provided by Automatic Identification System (AIS).

neXat's platform will provide monitoring information through APIs for SEAFAR to collect in a machine-to-machine format and integrate into its dashboard for the remote captain to access. neXat will also develop a system that continuously monitors all the communications means that the ship might use at any time, including 4G, 5G and satellite. The result is a heatmap of the availability of different telecommunications technologies as well as the quality and performance of the connections.

The space assets that will be used in SeaNext are SatNAV, SatAIS and SatCOM. SatNAV for vessel positioning using GNSS receivers is also used. This capability is crucial, as GNSS receivers can receive signals from multiple satellite systems, leading to improved positioning accuracy.

Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

AMETEK, a provider of amplifiers and electromagnetic compatibility (EMC) testing equipment for the defense, medical, communications and automotive markets, announced the acquisition of **Amplifier Research Corp. (AR RF/Microwave Instrumentation)**, a manufacturer of RF and microwave amplifiers and EMC testing equipment. AMETEK has a diverse product portfolio including RF and microwave instrumentation amplifiers, hybrid power amplifier modules, antennas and control software used to provide high-end EMC solutions. Amplifier Research is headquartered in Souderton, Pa., and has annual sales of approximately $60 million. Amplifier Research joins AMETEK as part of its Electronic Instruments Group.

Infineon Technologies AG announced the closing of the acquisition of **GaN Systems Inc.** The Ottawa-based company brings with it a broad portfolio of GaN-based power conversion solutions and leading-edge application expertise. All required regulatory clearances have been obtained, and GaN Systems has become part of Infineon effective as of the closing. Infineon now has a total of 450 GaN experts and more than 350 GaN patent families, which expands the company's leading position in power semiconductors and considerably speeds up time-to-market. Both companies' complementary strengths in IP and application understanding, as well as a well-filled customer project pipeline, put Infineon in an excellent position to address various fast-growth applications.

Stellant Systems Inc. and **Comtech Telecommunications Corp.** announced the companies entered into a definitive agreement under which Stellant will acquire Comtech's Power Systems Technology (PST) product line for a total cash purchase price of $40 million, which includes a preliminary sales price of $35 million and contingent consideration up to $5 million based on the achievement of certain targets. The transaction was unanimously approved by the board of directors of both companies. Stellant is a portfolio company of Arlington Capital Partners, a Washington, D.C.-based private equity firm with extensive experience investing in regulated industries. The acquisition of the PST product line will strengthen Stellant's portfolio of RF amplification products.

Emerson announced it has closed its acquisition of **NI** at an equity value of $8.2 billion. The acquisition of NI advances Emerson's position as a global automation leader and expands its opportunity to capitalize on key secular trends like nearshoring, digital transformation and sustainability and decarbonization. NI brings a portfolio of software, control and intelligent devices that is expected to accelerate Emerson's revenue growth in its 4 to 7 percent organic growth target. NI increases Emerson's end market exposure in discrete markets, which will be Emerson's second largest industry segment, and with approximately 20 percent of sales in software, NI also increases Emerson's exposure to high-growth industrial software markets.

COLLABORATIONS

To assist firms interested in deploying AI to enhance their businesses, the **Commonwealth of Massachusetts** has launched an innovative pilot program called AI Jumpstart. This program funds new computing infrastructure at Boston's **Northeastern University (NU)** to connect industry partners with world-class facilities and university researchers across several AI disciplines. As an industry partner, **Keysight** has been involved in the project since funding was announced. As a partnership between the state economic development agency **Massachusetts Technology Collaborative** and Northeastern, the AI Jumpstart is based on a 15-year relationship that has invested in university-based research and development projects that have successfully engaged business and industry.

Airbus and **Northrop Grumman** announced the signing of a Memorandum of Understanding to develop and foster a strategic partnership in military satellite communications for the U.K.'s future wideband SKYNET military satellite communications programme. The agreement between the two leading European and U.S.-based defence and space firms will bring together the latest technology and will see the two companies' experience, knowledge and capability mutually shared to address military satellite communication requirements for the British Ministry of Defence. Airbus and Northrop Grumman say the partnership is vitally important as military forces increasingly use space-based assets to fulfill their missions and require specialised technology to transmit information via space.

NEW STARTS

To support the market's interest in their mmWave products, **mmTron** moved into larger offices. Two probe stations from FormFactor enable on-wafer testing. One is capable of interfacing with frequency extenders for measurements to THz. The new space also includes wire bond assembly, incoming and outgoing inspection and inventory storage with N2 desiccators, as well as offices for team members. mmTron is still in Redwood City, less than half a mile from their previous location.

ACHIEVEMENTS

CesiumAstro celebrates the successful initial tests of its CommPack cross-link communications payload on the NASA Starling mission's CubeSats. With these tests complete, the CommPack system achieves TRL 9 status, the highest technology readiness level, and the NASA Starling team is set to begin communications experiments with the cross-link radios. Launched aboard

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a Rocket Lab Electron rocket in July 2023, the Starling mission is flying a collaborative "swarm" of spacecraft that will perform coordinated activities in various areas, including in-space network communications, relative navigation between spacecraft, autonomous maneuver planning and execution and distributed spacecraft autonomy.

CONTRACTS

The **U.S. Army** awarded **L3Harris Technologies** full-rate manpack and leader radio production orders under the Handheld, Manpack & Small Form Fit (HMS) program. These orders, totaling more than $247 million, deliver critical cryptographic modernized communications with resilient waveforms to help ensure the Army's Integrated Tactical Network can survive in the modern battlespace. The L3Harris AN/PRC-158 and AN/PRC-163 radios leverage software-defined architectures and integrated cross-banding between waveforms. The radios include key software-defined capabilities that will incorporate satellite communications while on the move. The radio technology also provides critical airborne platform communications that enhance the connection between ground assets and aerial networks.

GlobalFoundries (GF) has been awarded $35 million in federal funding from the U.S. government to accelerate the manufacturing of GF's differentiated GaN on silicon semiconductors at its facility in Essex Junction, Vt. This funding brings GF closer to large-scale production of GaN chips, which are unique in their ability to handle high voltages and temperatures. These chips are positioned to enable game-changing performance and efficiency in 5G and 6G cellular communications for infrastructure and handsets, automotive and industrial IoT, as well as power grids and other critical infrastructure. With the new $35 million in funding awarded by the **Department of Defense's Trusted Access Program Office**, GF plans to purchase additional tools to expand its development and prototyping capabilities.

Mercury Systems Inc. announced an agreement with the **U.S. Navy** to develop manufacturing capabilities that would allow commercial photonics chiplets to accelerate edge processing in defense applications. The Office of the Under Secretary of Defense for Research and Engineering Trusted and Assured Microelectronics Program's Project KANAGAWA aims to mature the domestic supply chain and manufacturing processes for multi-chip packages, where co-packaged optics are integrated with electronic ICs to enable long-reach and high bandwidth data transfer. Compared to conventional copper connections, photonics uses optical fibers to enable orders of magnitude improvements in data bandwidth at a fraction of the power needed.

CAES has been awarded a contract from the **U.S. Navy** for production of the AN/ALQ-99 low band consolidation (LBC) transmitter. Total funding through 2025 to sup-

port both the U.S. Navy and Royal Australian Air Force (RAAF) is expected to exceed $55 million if all options are exercised. This award also includes new special test equipment and follows a contract for the initial pre-production phase of the LBC. The LBC is a modification to the AN/ALQ-99 low band transmitter (LBT). CAES has a proven history of developing, producing and delivering LBTs. CAES provides these components for the U.S. Navy and RAAF EA-18G Growler Airborne Electronic Attack fleets.

PEOPLE


▲ *Guillaume Sassus*

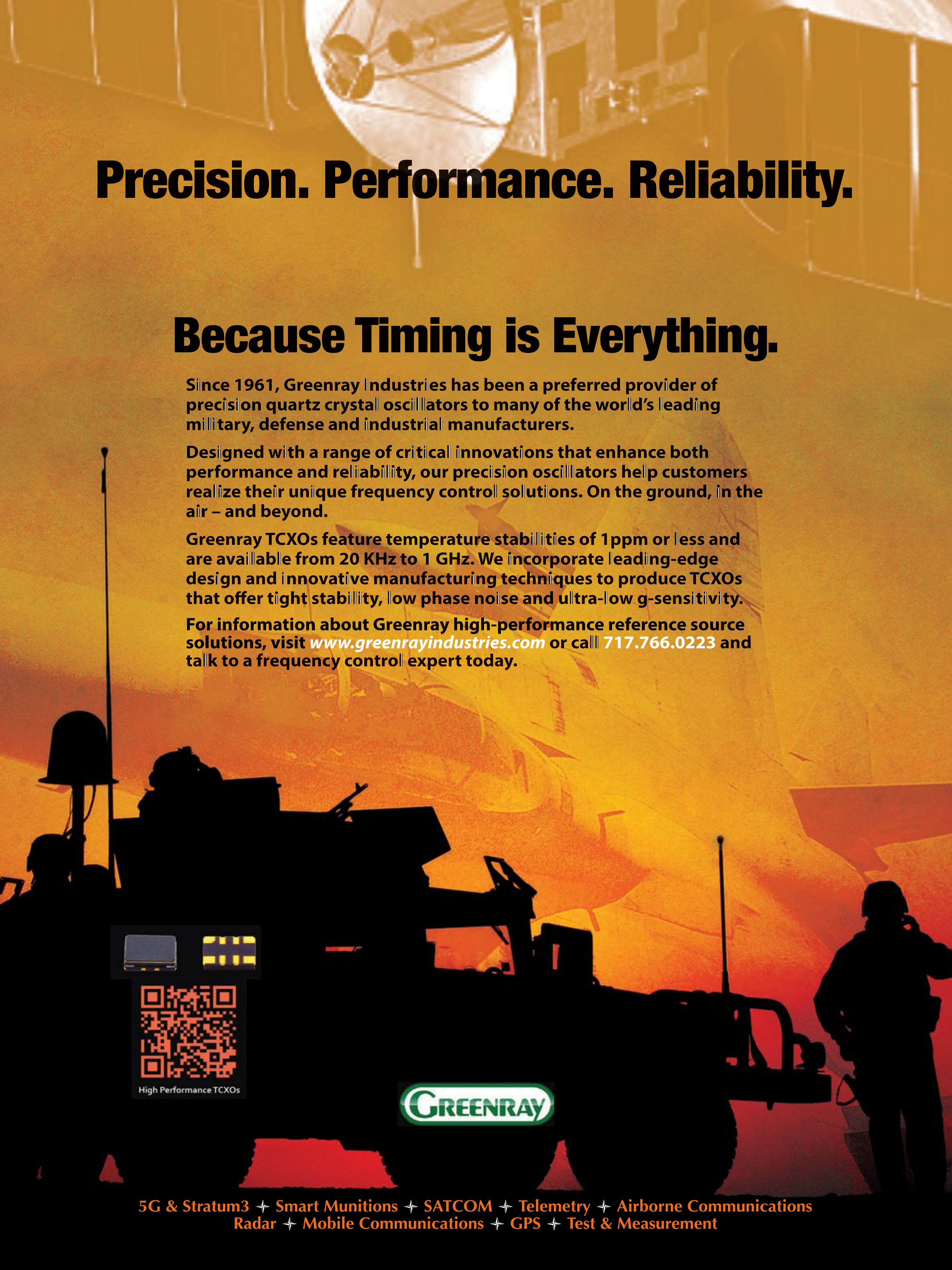
Microwave Vision Group (MVG) announced the appointment of **Guillaume Sassus** as CEO, effective October 9, 2023. He succeeds **Philippe Garreau**, who has led the group for almost 30 years and will now assume the role of president. This appointment comes at a time of strong growth for MVG, supported by the European investment group HLD. Sassus has worked for over 15 years in aerospace and optics, B2B industries where innovation is key, and for five years in management consulting. He will bring to MVG a dual industrial and strategic expertise that will be precious in accelerating the development of new technological bricks and in supporting its customers ever more closely in the design of their products.


▲ *Dan Sallet*

BAE Systems Inc. has named **Dan Sallet** as its senior vice president for finance. In his role, Sallet will be responsible for the financial operations of the company's U.S.-based businesses, which employ more than 35,000 employees in the U.S., U.K. and Sweden, and generated 2022 sales of nearly $12.6 billion. Sallet will report to BAE Systems, Inc. President and CEO Tom Arseneault and serve as a member of the Inc. senior leadership team. Sallet succeeds Guy Montminy, who will be retiring next year.

REP APPOINTMENTS

Altum RF announced a sales representative agreement with **MEV Elektronik Service GmbH (MEV)**, covering customers located in Germany, Austria and Switzerland. MEV specializes in providing engineering and technical support for the electronic components, modules and systems it distributes. MEV also offers expertise and relationships in the industrial automation, communications technology, aerospace and defense and medical industries. Altum RF is an international company with strategic partnerships and office locations that span the globe to support its growing product portfolio.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INVITED PAPER

The Need to De-Risk Gallium Material Supply Chains

Matthew Funaiole, Brian Hart and Aidan Powers-Riggs
Center for Strategic and International Studies, Washington, D.C.

In July 2023, China put the world on notice when its Ministry of Commerce announced new licensing requirements for exports of the critical minerals gallium and germanium. The restrictions were widely seen as part of Beijing's response to U.S.-led efforts to restrict China's access to advanced semiconductors and chipmaking equipment. While the urgency of this announcement has retreated from the forefront of the news, any change in policy presents a threat to the RF and microwave industry.

China is the world's leading supplier of both minerals, but its control over gallium is especially notable. In 2022, it produced a staggering 98 percent of the world's supply of raw gallium.[1] For the growing set of industries that rely on gallium material, China's moves should raise eyebrows. Chinese customs data shows that the country's gallium exports dropped to zero in August, 2023[2] demonstrating the potential extent of its restrictions.

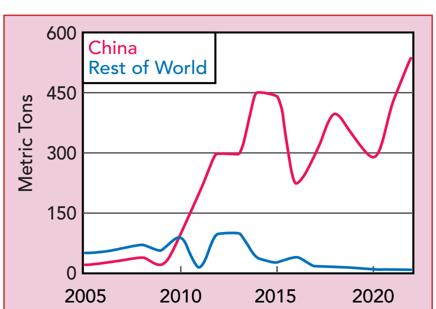

Fig. 1 **Global primary gallium production. Source: "Gallium Statistics and Information," National Minerals Information Center, USGS, https://www.usgs.gov/centers/national-minerals-information-center/gallium-statistics-and-information.**

While gallium is not especially rare, its production has become increasingly concentrated in China. This is due to years of government-supported production that forced most global producers out of business over the past decade. As a result, there are currently few alternatives to Chinese suppliers in the short term.

Gallium's critical role in modern electronics supply chains, particularly in advanced defense equipment like next-generation missile defense, radar, electronic warfare and communications systems, makes China's stranglehold over its supply a critical vulnerability for the U.S. and its partners. While severe disruptions have yet to materialize, this episode should serve as a call to action for public and private stakeholders in the U.S. and allied countries to coordinate on clear steps to de-risk their critical mineral supply chains. ***Figure 1*** shows how quickly China's dominance in primary gallium production has grown compared to production from the rest of the world.

GALLIUM: A NATIONAL SECURITY VULNERABILITY

China's decision to target gallium with export restrictions was likely motivated by the metal's importance to the defense sector. Gallium is an essential input into compounds like gallium arsenide (GaAs) and

gallium nitride (GaN), which are used to fabricate direct and wide bandgap semiconductors found in RF devices, power electronics and optoelectronics. The performance of these chips at higher voltages, temperatures and frequencies makes them especially well-suited for military applications.

For decades, advanced military systems, from radars and missile defense to satellites and electronic warfare systems, have used GaAs MMICs in transmit/receive applications due to their performance, efficiency and resilience to heat and radiation. In recent years, GaN has emerged as an even more capable alternative to GaAs in RF power applications and the falling fabrication costs of GaN substrates[3] are spurring widespread adoption.

GaN is revolutionizing modern radar, allowing new radar modules to track smaller, faster and more numerous threats from nearly double the distance. Many of these cutting-edge radar systems are powered by several thousand gallium-enabled chips. U.S. and allied armed forces are swiftly incorporating GaN-enhanced radars into their most important platforms. In 2019 Raytheon was awarded a $383 million contract to build the first six GaN-enabled active electronically scanned array (AESA) radars for the U.S. Army's Lower-Tier Air and Missile Defense Sensor (LTAMDS), which are being integrated into Patriot missile defense units and other systems.[4] In June 2023, Poland secured the first foreign sale of the LTAMDS radar system and other key U.S. allies are likely to follow.[5] In addition to Poland, the U.S. military is also helping key international partners like South Korea and Saudi Arabia to integrate GaN-enhanced devices into their radar systems.

Meanwhile, Northrop Grumman is developing the AN/APG-85, an advanced GaN-based AESA radar for the F-35 Lightning II Joint Strike Fighter and the U.S. Marine Corps has deployed Northrop's AN/TPS-80 ground-based radar system since 2019. In 2022, the U.S. Department of Defense (DOD) awarded Raytheon a $3.2 billion contract to equip up to 31 vessels with GaN-powered AN/SPY-6 system radars, including the navy's new Arleigh Burke-class Flight III destroyers, aircraft carriers and amphibious ships.[6] These upgrades are poised to bring about a sea change in the ability of U.S. and allied forces to defend against emerging threats like hypersonic missiles, next-generation stealth aircraft and unmanned systems.

Beyond direct defense needs, gallium is increasingly essential for a broad set of commercial products. These products are found in applications like 5G base stations, smartphones, solar panels and electric vehicles. Some industry experts even see gallium compounds as a potential way to move beyond

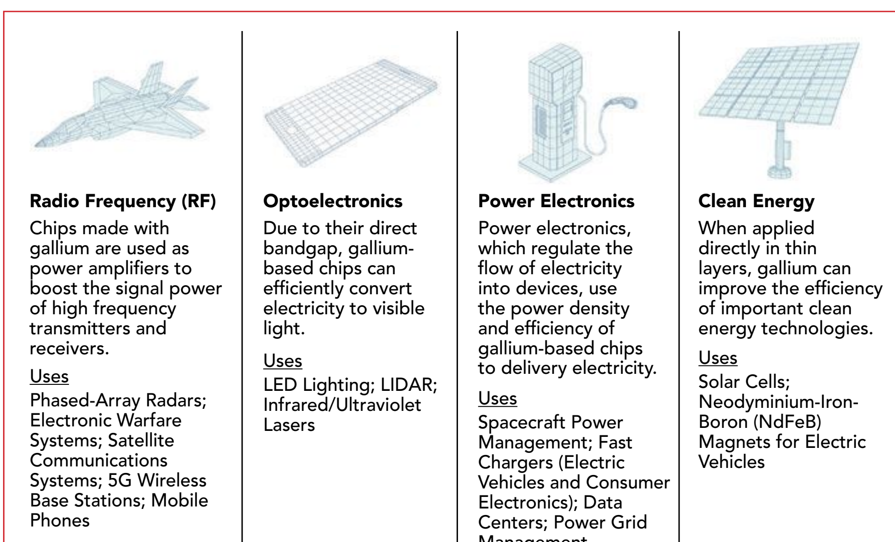

Fig. 2 Applications and uses for gallium-based devices. Created by CSIS. Reprinted with permission. Source: Authors' research and analysis based on multiple sources.

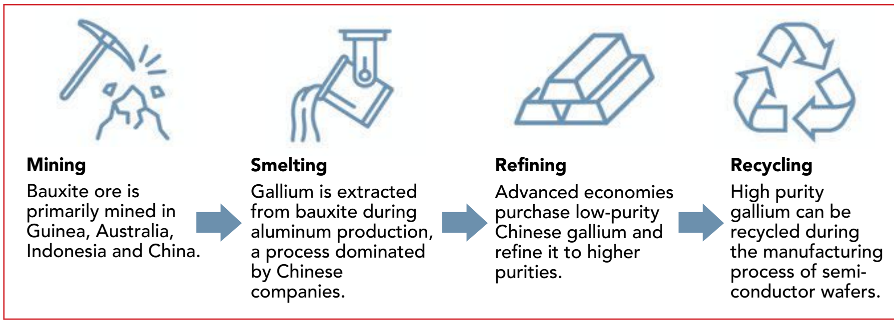

Fig. 3 Gallium production process. Created by CSIS. Reprinted with permission. Source: Authors' research and analysis based on multiple sources.

silicon-based chips as advanced chipmaking begins to push the limits of Moore's law.[7] ***Figure 2*** shows some of the advantages and uses of gallium-based devices in a variety of applications.

The growing need for gallium as a raw material in both defense and critical industries has ensured that supply interruptions would be costly. Precise economic impacts are difficult to quantify, but experts from the U.S. Geological Survey (USGS) estimate that a 30 percent supply disruption of gallium could cause a $602 billion decline in U.S. economic output or 2.1 percent of gross domestic product.[8] The cascading impacts on industrial production could cause major setbacks to the manufacturing of key defense systems, particularly those that rely on GaN chips.

China does not yet appear to be pursuing a full export embargo of gallium, leaving room for Beijing to escalate further. The Commerce Ministry announced the restrictions a full month before they went into effect, giving many firms some time to stockpile much of their short-term needs. Starting in September, it appeared to be approving gallium export permits even for U.S.-based firms. Still, without coordinated steps to diversify their supply, the U.S. and its allies will remain vulnerable if China chooses to further tighten restrictions in the future.

HOW DID WE GET HERE?

China's near monopoly over gallium production is closely tied to the rise of its aluminum industry. Gallium differs from some other key minerals, such as lithium, nickel and cobalt, in that it is normally not recovered directly from the earth.

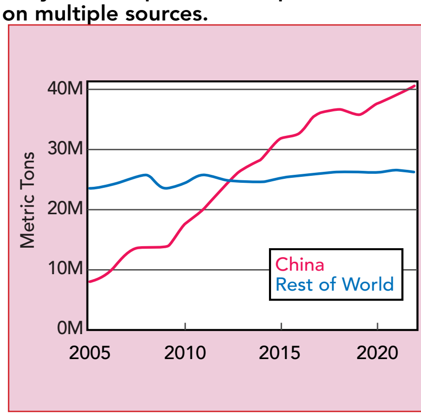

Fig. 4 Global aluminum production. Source: "Primary Aluminium Production," International Institute, July 20, 2023, https://international-aluminium.org/statistics/primary-aluminium-production/.

Instead, roughly 90 percent of the world's gallium supplies are derived as a byproduct of processing bauxite, the primary ore for aluminum. Much of the remainder is extracted from zinc or coal tailings. Raw gallium is then refined into higher purities before it can be used for most applications, a process that has also gradually shifted from the U.S. and other advanced economies toward China. An overview of the gallium production cycle, from mining to recycling, is shown in ***Figure 3***.

Over the past two decades, China's rapid industrial buildup has driven an explosion in the country's aluminum production. Helped along by expansive government subsidies and tax incentives, China's production of aluminum skyrocketed ten-fold (from 4.2 to 40.2 million tons) between 2000 and 2022.[9,10] By 2022, China supplied nearly 60 percent of the world's aluminum. China's aluminum production increase versus the rest of the world is shown in ***Figure 4***.

Beginning in the late 2000s, China's economic planners also put the

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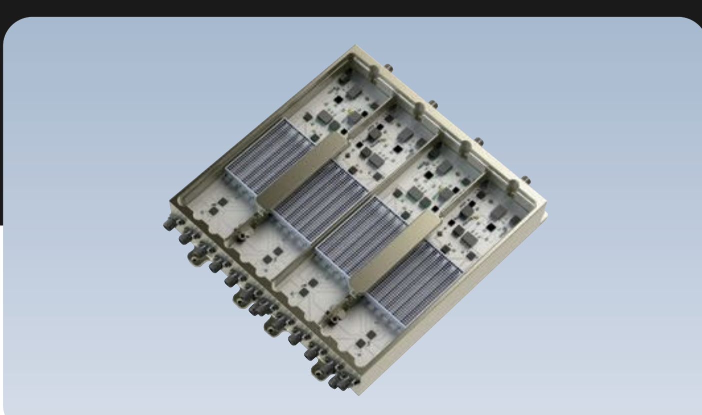

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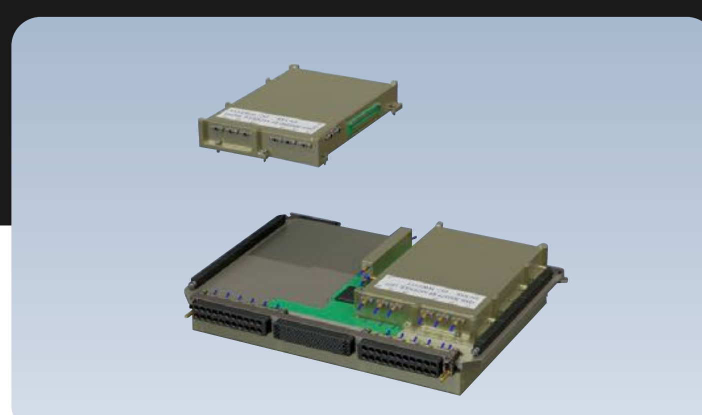

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weight of the state behind the country's nascent LED and display industries, both of which rely on chips made with gallium. Government support flowed to major aluminum processors like the Aluminum Corporation of China (Chalco) to encourage them to install the equipment needed to extract gallium from aluminum tailings. As a result, from 2005 to 2015, China's production of low-purity gallium exploded from 22 metric tons to 444 metric tons.[11]

The flood of cheap gallium from China into global markets created oversupply, triggering severe price fluctuations of the metal throughout the early 2010s. Top suppliers in the U.K., Germany, Hungary and Kazakhstan found it no longer profitable to produce gallium and were forced to shutter production. The U.S., which began offshoring much of its domestic mining capacity in the 1970s and 1980s, saw one of its last remaining refined gallium production facilities shut down in 2020. China was left as virtually the only supplier in the world.

FUTURE RISKS

Beyond primary-stage production of gallium, Beijing is also seeking to develop a competitive domestic industry for higher-value segments of the gallium-based semiconductor supply chain. Chinese experts specializing in wide bandgap or "third-generation" semiconductors have signaled that their efforts are aimed at technologically leapfrogging the U.S., Europe and Japan.[12] They are also clearly tied to China's military modernization goals.

While U.S., European and Japanese firms lead at the cutting-edge of wide bandgap chip production, China has identified the technology as a key focus area and is seeking to close the gap. The country's 14th Five-Year Plan, its top national economic blueprint released in 2021, explicitly names GaN along with silicon carbide as targets in its technological development plan. Making headway in the development of gallium-based semiconductors could offer China unique opportunities to advance its drive for technological self-sufficiency. In emerging gallium-based compounds like GaN and gallium oxide that are still in the early stages of development, China can potentially lock in early-mover advantages in ways similar to its success at capturing the lead in producing advanced batteries for electric vehicles.

It also appears that the drive for technological self-sufficiency and superiority is taking place in more channels than just the development facilities. Alongside political and financial support from Beijing, there have been concerted efforts by Chinese individuals, firms and entities to target GaAs and GaN technologies from companies in the U.S. and other advanced economies that have run afoul of laws and government oversight. The Chinese entities behind some of these activities are often linked to the People's Liberation Army. ***Figure 5*** illustrates some of the issues that have arisen from China targeting foreign gallium technologies since 2010.

Both China's civilian and military electronics sectors have reaped the rewards of Beijing's push to develop its

gallium-based semiconductor industry. In 2021, China's leading military radar manufacturer, China Electronics Technology Group Corporation (CETC), released a family of next-generation GaN-backed radar systems called Lingdong. CETC claims that these systems can easily detect stealth aircraft and cruise missiles.

On the commercial side, China's top GaN fabrication firm, Innoscience, has reached world-leading status with two eight-in. dedicated GaN foundries. These foundries have come online ahead of competitors in the U.S. and Japan. In addition, Chinese scientists have recently made significant breakthroughs in producing gallium oxide wafers, despite U.S. export controls on the material.[13]

There are several consequences of China's emerging capabilities at the cutting-edge of gallium semiconductor manufacturing. A key consequence is that China will grow less dependent on imports from countries like Japan, the U.S. and South Korea for the highly advanced chips needed as inputs for its industrial production. This reduced reliance could help insulate China's domestic firms from broader supply chain disruptions that would result if it further escalated its export controls on gallium or other raw materials.

TOWARD DE-RISKING

During the G7 summit in May 2023, the leaders of the world's leading economies collectively advocated for "de-risking" their economic interdependence with competitive nations like China. Addressing the vulnerabilities in gallium supply chains presents a readily achievable objective for U.S. and allied policymakers as they reevaluate their economic ties with Beijing. While no country can achieve complete self-reliance in natu-

Year	Description
2010	A federal jury in Massachusetts convicted two Chinese nationals of unlawfully exporting export-controlled electronic components containing GaAs technology to military entities in China.
2015	The Committee on Foreign Investment in the U.S. (CFIUS) blocks a $2.9 billion bid by Chinese investors for the LED-component subsidiary of Philips, a major Dutch lighting firm. CFIUS cited concerns that China sought the firm's GaN technology for military purposes.
2015	Taiwan's Ministry of Justice arrests several employees of Win Semiconductors, a leading GaAs foundry, for stealing proprietary information and passing it to Chengdu GaStone, a PLA-linked semiconductor firm on the U.S. Entity List.
2016	CFIUS blocks $713 million bid by a Chinese firm for German GaN chipmaker Axitron, citing threats to U.S. national security.
2018	The U.S. Department of Justice indicts two individuals for stealing confidential technologies from Wolfspeed, a leading GaN manufacturer in the U.S. (and a major supplier for the U.S. military). The stolen technologies were being transferred to two of the PLA's primary centers for radar development, AVIC 607 and CETC's 14th Research Institute.
2023	Efficient Power Conversion Corp (EPC), a major U.S. GaN firm, files a complaint in U.S. Courts against Innoscience, alleging that Innoscience recruited two EPC employees for executive roles shortly before introducing a suite of products visibly identical to EPC's.

Fig. 5 **Issues from China's efforts to target foreign gallium technologies. Source: Authors' research and analysis based on multiple sources.**

ral resources, strategic domestic investments and cooperative efforts with both allied governments and the private sector can enable the U.S. to reduce its dependence on China and mitigate the susceptibility of critical supply chains to geopolitical disruptions.

Ramping up the production of gallium outside of China will require time, political will and risk-tolerant investment. Although bauxite is plentiful within the U.S. and several of its allies, most notably Australia, firms face barriers such as environmental regulations, long approval timelines, low profit margins and a lack of expertise that discourage the investments needed to restart production. Additionally, the industry-favored compound used to extract gallium, called Kelex 100, is predominantly supplied by Chinese firms, further complicating efforts to reduce reliance on China for early-stage production.

An effective response would follow five major lines of action:

The U.S. should invest in gallium extraction and refinement capabilities: Supported by Defense Production Act authorities, the U.S. DOD should invest in the conditions for firms to establish and maintain gallium production facilities. Targeted public-private agreements based on investment, tax incentives or other tools could provide the necessary conditions for firms to establish and maintain gallium production facilities. There is currently one active plant in the U.S., based in Louisiana, that processes bauxite into aluminum. Given the proper incentives, this plant could install the equipment needed to extract gallium.

Washington should collaborate with allies and partners to scale up overseas gallium extraction and refinement capacity: Working with partner countries that have previously produced gallium, like Germany, or have known gallium reserves, like Australia, the U.S. government and private firms can support investments to scale up overseas production facilities and establish frameworks to guarantee privileged access.

The federal government should support and promote gallium recycling: Ramping up the recycling of gallium may offer a way of alleviating supply chain issues in the short or medium term. Significant quantities of gallium can be recycled at various stages of the manufacturing process. The U.S. and its partners should invest in building on existing recycling capabilities and support efforts to do so in allied countries like Japan.

The DOD should maintain a minimum one-year stockpile of gallium for the defense industry: The DOD's Defense Logistics Agency (DLA) lists gallium as a "material of interest" but has not made any purchases for stockpiling within the past decade. Consulting with Congress, DLA should add gallium to the National Defense Stockpile, working with private industry and foreign partners to ensure U.S. defense needs are covered for at least one year.

The U.S. International Trade Commission should enhance data collection and transparency in U.S. gallium production and consumption. Improved access to official data on more steps in the gallium supply chain would help private firms, policymakers and defense officials better assess the state of the market and U.S. vulnerabilities. ■

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INVITED PAPER

5G Needs Microwave in Backhaul

Jimmy Yu
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Cellular or mobile radio access networks (RAN) have become critical infrastructure that ensures voice and data connectivity exists wherever you are. At least once a day, people glance at their smartphone to make sure a signal is present by the number of bars shown on the screen and there is a certain amount of comfort in knowing that the more bars shown means the phone is well connected to the internet and to the world. But what if it does not? Because it really does not.

Often forgotten behind the buzzwords of 4G and 5G is the transport layer that connects the radio to the mobile core. This transport layer, referred to as mobile backhaul (MBH), is one of the critical components of a cellular network that ensures a great connection between the phone and the internet. Without it, the "bars" on the phone screens are meaningless.

TWO OPTIONS EQUATE TO TWO CHOICES, NOT ONE

Operators, like any other company in a competitive market, will increase their market share and revenue while enjoying higher profits if they are first to market and offer a superior product experience. This principle drove the rapid deployment of 4G and is driving the rapid deployment of 5G. Therefore, when operators begin to roll out 5G networks, each one will face the same challenge: obtaining full population coverage in the shortest time possible to ensure a great customer experience because anything less tarnishes the company brand. To create the population and geographic coverage, operators need to deploy 5G in a multitude of environments: urban, suburban and rural areas. In each of these locations, the biggest concern will be getting the backhaul in place because, without a good MBH network, the user experience will suffer.

Most people assume that the best MBH technology is the one that uses fiber and therefore, all MBH should be done with a fiber system. This is true in theory, but in reality, the use of a fiber system is limited by the availability and cost of fiber. The alternative is to use a wireless technology for MBH such as point-to-point (PTP) or point-to-multipoint (PTMP) microwave transmission systems, a technology that is not reliant on a physical cable and can be installed in days rather than months. Hence, there are and always will be two choices for MBH: fiber and microwave. ***Table 1*** shows examples of the different types of MBH networks, along with use cases, advantages and disadvantages.

On a global basis, the use of fiber systems exceeds microwave systems, but in many major regions of the world, including Europe, Latin America and Asia Pacific (excluding China) microwave systems are used more often than fiber systems because fiber is too costly to install or impractical to use. Therefore, microwave systems are needed for operators to achieve full 5G coverage, or stated another way, full 5G coverage cannot be achieved without microwave backhaul.

TABLE 1

ANALYSIS OF FIBER AND MICROWAVE FOR MBH SYSTEMS

	Fiber System	Microwave System
Two Options for Mobile Backhaul		
Technology	• Optical transport (WDM) • Passive optical network (PON) • Carrier Ethernet switch and router	• PTP microwave transmission • PTMP microwave transmission
Best When	• Fiber to the cell tower is available or the cost to install fiber to the tower is low • Major aggregation site or hub where backhaul capacity will need to scale beyond 20 Gbps • Operator has other services such as fixed broadband that can leverage the fiber infrastructure	• Fiber is unavailable or too costly to lay • Leasing backhaul capacity or dark fiber from a third party is too high or unavailable • Site location is temporary • Site requires a link capacity of <20 Gbps • Operator wants control of MBH network without the cost of fixed network infrastructure
Two Choices for Mobile Backhaul		
Positives	• Future proofed: fiber capacity can scale to higher bandwidths • High service level: service quality usually not affected by adverse weather	• Versatile: can be deployed anywhere, including rugged terrain, across bodies of water and in deserts • Resilient: more resilient than fiber to many natural disasters • Fast time-to-market: installed in days
Negatives	• Difficult to install fiber: involves digging trenches and gaining property rights to lay down fiber • Slow time-to-market: takes up to one year to install fiber • Possible fees: Lease dark fiber or backhaul service from a third party	• Link stability: antenna alignment is crucial to maintaining high link speeds • License fee: license spectrum • Rain fade: adverse weather (wind and moisture) can reduce link speed

Source: Dell'Oro Group

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		Software-Defined Networking

Fig. 1 The evolution of microwave transmission performance. Source: Dell'Oro Group

Microwave Transmission Evolution

Before there were fiber optics, there was microwave transmission. As early as 1930, microwave transmission was used in communication networks. During this early stage, the microwave application was for the transport of voice across short distances. In time, operators installed microwave systems across continents to deliver tens of thousands of voice circuits to connect cities along one coast to those on the other.

Since those early days, microwave transmission technology has evolved, changing to meet the needs of every new generation. When cellular technology emerged, microwave transmission was used to transport hundreds of voice circuits; when 2G arrived, it was used to transmit kilobits of voice traffic and with 4G, hundreds of megabits of data. Over this period, networks shifted away from carrying lots of voice traffic towards transmitting an ever-increasing amount of data, requiring microwave equipment to grow from carrying analog voice to carrying large amounts of packets. Some details on this microwave transmission evolution are shown in ***Figure 1***.

The newest microwave transmission equipment designed to meet the requirements of 5G backhaul has all the latest features, including packet switching, carrier aggregation and software-defined networking. These technologies increase the link capacity, improve performance and reduce operating costs. Dell'Oro Group estimates that more than one-third of all 5G cell sites will need a PTP microwave system for backhaul in the next five years. Also, while not a new technology, 5G is driving the use of E-Band spectrum (70 and 80 GHz).

E-Band spectrum for microwave transmission has been available for decades. While this spectrum offers higher throughput speeds, it initially targeted campus networking applications due to its shorter spans and higher costs. Its use steadily shifted to MBH when the 4G standards required backhaul links to have speeds as high as 1 Gbps.

The interest in E-Band continued to grow with 5G since the requirements laid out were for higher backhaul links and lower latencies. In time, new E-Band systems were released that could transmit up to 20 Gbps in a single box across urban and suburban spans stretching multiple kilometers. With these new products, prices also declined with the use of lower-cost chipsets. Today, the average price premium for an E-Band system that can transmit 10x more bandwidth than a microwave system operating at a standard frequency of less than 40 GHz is only 60 percent. Dell'Oro Group estimates that about 80 percent of new E-Band radios are purchased for use in MBH applications.

Another benefit of using E-Band is that these frequencies in the 70 and 80 GHz range are license-free or lightly licensed in a number of countries, lowering the spectrum licensing costs compared to those required for standard microwave frequencies. The biggest problem with using E-Band spectrum for PTP microwave is the high amount of signal degradation caused by rain, wind and heat. Rain fade occurs with all microwave signals, but it is worse at higher frequencies, and E-Band is at the highest frequencies currently used for backhaul. Wind and heat create alignment issues since E-Band signals have a very small beam angle and the alignment between two radios can be easily disturbed by high winds and temperatures if

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AMP2070A	1.0-6.0GHz	150	100	52
AMPP2070D-LC	1.0-6.0GHz	200	150	53
AMP2030-LC	1.0-6.0GHz	300	200	55
AMP2030B-LC	1.0-6.0GHz	400	250	56
AMP2030D-LC	1.0-6.0GHz	750	400	59
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AMP2030-LC-3KW	1.0-6.0GHz	3000	2500	65

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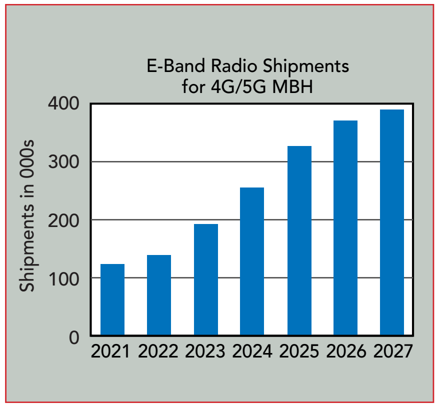


▲ **Fig. 2** **Forecast for E-Band radio shipments. Source: Dell'Oro Group**

the microwave radio is not mounted on a stable structure.

However, manufacturers have been steadily addressing these issues in a few ways. The first is to introduce multi-band systems that combine a traditional radio with an E-Band radio on a single link. This new solution strengthens the signal quality across the two radios and ensures that, in the event of high rainfall, at a minimum, the data will traverse across the traditional frequency band. The second way that manufacturers ameliorate these problems is to increase the E-Band radio power to both extend the signal reach and improve link availability. The last technology advancement, which is more mechanical, addresses the issue caused by high winds that cause the tower holding the E-Band radio to sway. To compensate for the shifting angle between two radios, manufacturers add active antenna alignment systems to constantly realign the two radios. This feature is also important when changes in temperature cause the towers to expand and contract, which also affects the radio alignment.

On the roadmap to address the growing demand for higher capacities and the needs of 6G, the development of microwave systems using new spectrum is underway. The new spectrum includes W-Band (92 to 114.5 GHz) and D-Band (141 to 174.8 GHz). Links using both bands are expected to be ready when 6G rolls out.

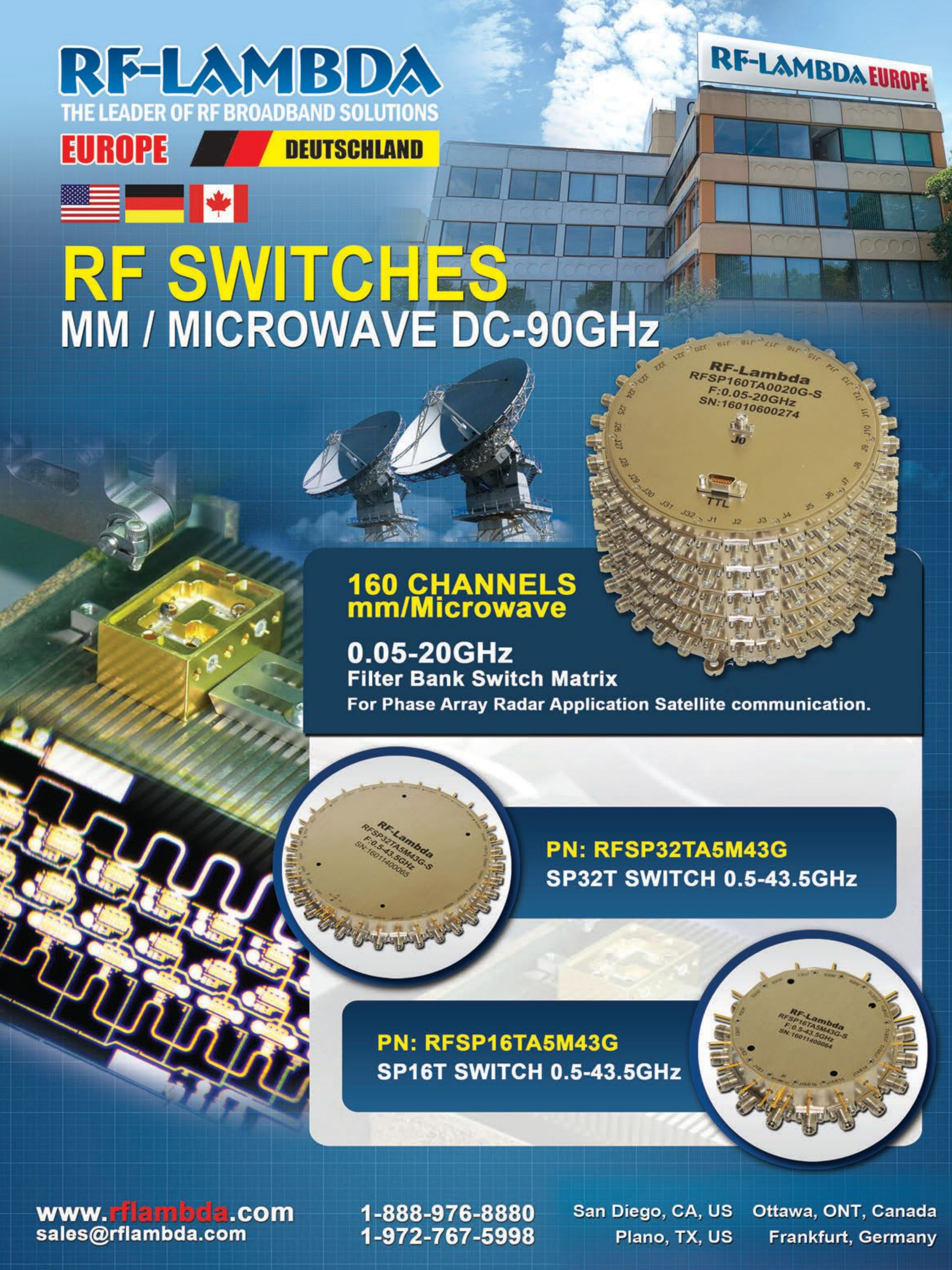
5G DRIVES MICROWAVE DEMAND

5G deployments began in 2018 and ramped up significantly in 2019. Most of these early deployments occurred in fiber-rich countries like China, Japan, South Korea and the U.S. They leveraged the fiber network put in place for 4G and the focus of the operators was on population coverage at existing customer locations. During the initial 5G rollout, there was little need for additional backhaul systems and when a new system was required, a fiber system was often chosen. Looking forward to the next phase, operators that started off using fiber are expanding their 5G network to territories where fiber is sparse and they will need to use microwave systems to save both time and money.

The rollout of 5G is still at an early stage when looking beyond the fiber-rich countries to regions that typically rely on microwave transmission for MBH, such as Europe, Latin America and Southeast Asia. These countries have just started to roll out 5G networks. Therefore, while microwave systems were not initially used when 5G first began rolling out in 2018, its share of cell sites is expected to rapidly increase to over 35 percent. Dell'Oro Group projects that over the next five years, $8 billion of PTP microwave systems will be purchased for 5G MBH. Among the technology segments comprising the microwave transmission market, E-Band systems are predicted to have the highest growth over the next five years due to MBH, growing at a compounded annual growth rate of over 20 percent. Dell'Oro Group's latest forecast for E-Band radio shipments is shown in ***Figure 2***.

SUMMARY

The transport layer is a critical component of a 5G network and can oftentimes define whether the user experience is satisfactory or not. It is also the most challenging to roll out if fiber is the only option since it can take years to install. Hence, operators continue to need microwave systems each time a new mobile RAN is deployed and for every generational upgrade. This is why, at the end of the day, 5G needs microwave in backhaul. ■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INVITED PAPER

Aerospace and Defense Applications Push Connector Boundaries and Require New Solutions

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Aerospace and defense (A&D) applications present some of the harshest environmental conditions for high performance electronic technologies. The mission-critical RF systems in these applications serve as the backbone for a range of vital technologies, including satellite communication, electronic warfare (EW), intelligence, missile guidance, radar and hypersonic systems. An ongoing evolution of hardware components and interconnection solutions is needed to meet the rigorous demands imposed by cutting-edge technologies and to ensure flawless operation in harsh and variable environments.

The effectiveness of RF systems fundamentally depends on the integrity of those hardware components and how they interact. While some installations can tolerate standard products, others necessitate custom-designed solutions tailored to unique specifications. In the ever-changing landscape of the A&D industries, there is a growing demand for high performance connectors that can withstand harsh conditions, severe vibrations and extreme temperatures while still delivering consistent performance.

In many applications, legacy connector designs, such as the sub-miniature push-on (SMP) shown in ***Figure 1*** or sub-miniature push-on micro (SMPM) are no longer sufficient to meet the requirements of evolving system technology. They are susceptible to issues like electromagnetic interference (EMI) and electromagnetic compatibility (EMC), lack environmental sealing and have the potential to disengage in response to the impact of a hard landing. These issues have spurred new RF interconnect designs to address these challenges more effectively. Among these, locking miniature push-on and locking miniature blind mate connectors have emerged as the new industry standard, specifically tailored to rectify the shortcomings of legacy technologies.

These advancements in connector designs are in response to the development of a new generation of A&D applications that continually push the boundaries of power handling and performance. These new connector types are engineered for high peak power conditions at high altitudes. These advancements will be crucial for the next wave of military communication systems designed for harsh environments.

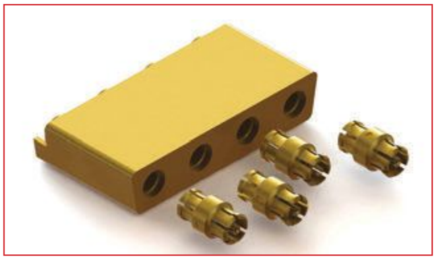


Fig. 1 **Representative assembly interface with SMP connectors.**

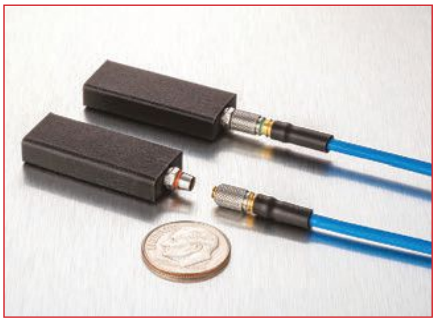


Fig. 2 **TLMP connectors.**

Fig. 3 **TLMP right-angle connectors.**

This article will detail how these developments are enabling reliable high performance in demanding, dynamic and harsh environments. It will explore the RF interconnect designs required to handle these challenges. Additionally, it will offer insights into emerging applications that demand multifaceted connectivity solutions.

THE NEW INDUSTRY STANDARD

Evidence of the evolution of interconnect designs can be seen in the increasing popularity of smaller-sized, O-ring sealed connector solutions that surpass their SMP/SMPM predecessors. These new solutions offer enhanced shielding, along with better environmental protection and mechanical retention. These new design efforts have resulted in the introduction of the Times locking miniature push-on (TLMP™) and Times locking miniature blind mate (TLMB™) connector families, which are specifically designed to address EMI concerns for applications that require environmentally sealed and shielded connectors. The TLMP connector type also addresses high vibration environments such as a carrier landing, weapons launch or similar harsh platform environments. ***Figure 2*** shows cables terminated with the TLMP connectors. ***Figure 3*** shows a right-angle connector using the TLMP design concept.

This connector class maintains the small form factor dimensions of SMPs while improving shielding and environmental and power handling capabilities over a frequency range from DC to 60 GHz. To minimize signal leakage, the mating component effectively covers the connector's slots. This construction enables these connectors to reduce EMI and EMC interference as well as liquid and salt ingress. The sealed design also enhances the resilience of the connector to harsh conditions and severe environments. Overlapping insulators eliminate a direct path to the ground from the center conductor to the outer shield, enabling higher voltage functionality.

In addition, the connectors incorporate a latching mechanism that improves their mating retention capabilities. This will differentiate these connectors versus threaded body alternatives. A verification feature with red (unlocked) and green (locked) color coding provides visual confirmation that the connectors are fully mated and locked. The locking blind mate version is equipped with an additional outer sleeve to increase the protection of the tines in blind mate applications. This color-coded locking mechanism is shown in ***Figure 4***.

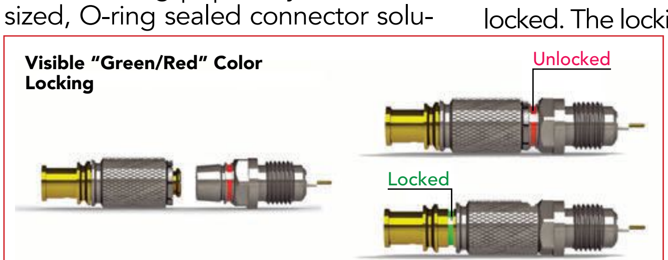


Fig. 4 **TLMP color-coded locking engagement.**

THE NEXT LEAP FORWARD

As harsh environment applications become more widespread, this increases the need for high-density, high-power connector solutions. As a result, locking miniature push-on and blind mate connectors are evolving to accommodate higher CW power and frequencies above 18 GHz. These new connector types become important to the reliability of communication systems. The connectors are well-suited for a wide range of applications, including densely-packed signal intelligence, electronics intelligence and EW systems.

The Times locking connector (TLC) is an example of this next leap forward. The connector was engineered with a 0.040 inch line size design and was built to handle higher transmit powers commonly found in aircraft systems. This connector utilizes a Polytetrafluoroethylen (PTFE) blend with ceramic filler dielectric instead of regular PTFE to improve the thermal dissipation characteristics. These new dielectrics possess 8x the thermal dissipation capacity of PTFE, giving this connector type better heat dissipation properties. This design change helps this connector type address high CW power applications at higher altitudes. This connector maintains its performance characteristics up to 23 GHz. An example of the TLC family of connectors is shown in ***Figure 5***.

There are cases where the TLC connector may be too large. To address these situations, the company has developed the Times locking push-on connector (TLPC). This connector handles high power levels in a considerably smaller form factor. The TLPC features a 0.030 inch line size and is available in multiple versions, including card edge and various edge launch configurations. The TLPC fam-

Fig. 5 **TLC connector design.**

ily is designed for many integration scenarios, whether that is threading the connector through the wall of a box or soldering it to the ground plane and the center pin or trace on the board. The design of the connector makes it suited for applications up to 32 GHz.

Sophisticated defense systems will incorporate numerous sub-system components and may include a dense collection of antennas. This increases the demand for cables and connectors, along with increasing the density of these components. The connector designs that have been described can be incorporated into multiport versions, eliminating conventional coupling nut schemes. This improves space utilization and operational efficiency. In this multiport configuration, the interfaces are integrated into male and female shells, effectively serving as bulkhead disconnects to enable higher interface densities.

APPLICATION EXAMPLES

The blend of advanced signal processing and sensing capabilities, combined with integrated hardware, helps unlock critical insights from very large data sets. This empowers military aircraft with more accurate and comprehensive systems and enhances functionality and safety. As this innovation accelerates, connectors must rise to the challenge of handling higher frequencies, faster data transmission speeds and increased power demands while being subjected to the same or harsher operating environments than previous generations of connectors.

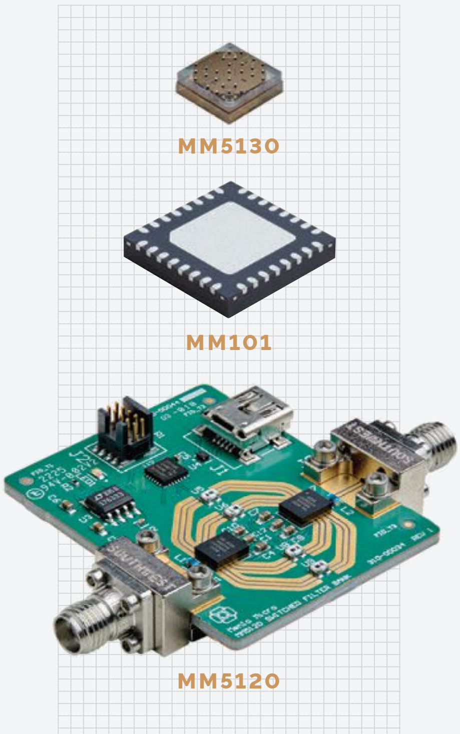
As defense systems have evolved, they have moved higher in frequency in search of more bandwidth. Many current systems operate in the 23 to 60 GHz frequency range and some systems go higher in frequency, enabling faster target detection and more precise tracking. The increasing channel bandwidth enables faster data transmission rates for incoming and processed signals. Onboard processors quickly filter and analyze this data to identify threats and facilitate rapid responses. Printed circuit boards (PCBs) are pivotal in supporting rapid connections between components or other PCBs in this sophisticated network. The design enhancements in the TLMP™-, TLMB™-, TLP- and TLC-series connectors target the emerging requirements of these applications to minimize signal loss and interference.

As airborne applications push the boundaries of speed and altitude, connectors must be able to handle elevated power levels while maintaining an appropriate balance between size, weight and power performance. As an example of these considerations, if an airborne system includes an active electronically steered array, the phased array radar will likely contain many small radiating elements to form and steer the radar beams. In this case, the radar processor box will orchestrate a complex symphony of RF and digital technologies, along with many radiating elements. The TLP- and TLC-series are engineered to support the inherent challenges in this demanding application. The speed barrier will be pushed even further by applications like hypersonic weapons. Connector designs incorporating materials like boron nitride dielectrics that can withstand the extreme temperatures caused by hypersonic speeds are emerging.

NEW REQUIREMENTS DEMAND COLLABORATIVE PARTNERSHIPS

New designs often require the connectors to maintain the highest performance in the harshest environments. Collaborating with experienced suppliers that have deep expertise and a trusted heritage of engineering development in mission-critical applications is an important consideration in the specification and design process. The chosen partner must thoroughly understand material technologies and possess in-depth knowledge of the specific applications, encompassing the aircraft, environmental factors and underlying physics. Manufacturers are finding that they need to adopt this holistic approach to ensure that they develop optimal solutions.

This holistic approach is increas-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ingly extending to incorporate the RF supplier. Given the highly complex nature of A&D systems, which rarely use standard solutions, the technical team must ask the right questions to understand the unique requirements of an interconnection application. A collaborative effort is proving instrumental in creating solutions that offer superior electrical, mechanical and environmental performance.

A&D system designers and integrators should consider the following when choosing an RF interconnect supplier:

Heritage and qualifications: Many RF suppliers offer a wide variety of standard capabilities, but A&D requirements are unique. Search for a partner with a wealth of relevant experience to help develop RF systems that can withstand the rigors of A&D environments, deliver reliable performance and adhere to stringent safety requirements.

Dedicated technical experts: Avoid partnering with a supplier focused on mass-market products. The first approach from these suppliers may be to offer the same product they sell to everyone else. Always request to engage with their technical experts. Additionally, the supplier should assist you in understanding the electrical and mechanical trade-offs specific to your application.

A large breadth of products: A supplier with an extensive product portfolio is better positioned to offer the ideal solution for a specific application. When selecting the best solution, it is advantageous to have a variety of options. These may include different cable constructions, various connector designs that range from low power to high power and a diverse set of assembly techniques that are all available from a single supplier.

Defense applications will likely mandate the use of acceptable materials and MIL-SPEC-compliant processes and requirements. Being able to meet these stringent standards is essential for the environments and conditions associated with every defense application and environment. However, a universal standard for material selection and design of a consistently reliable RF solution does not exist. Instead, the expertise and comprehensive range of product options from a supplier become invaluable tools to ensure an optimal solution. Some of the factors to consider:

Manufacturing execution: In an ideal scenario, the RF supplier possesses the full spectrum of technology and products that are required and understands how to integrate them into a finished product. It then becomes important to evaluate the manufacturing operations. Does the company have robust facilities and well-defined processes that ensure seamless execution? Cleanroom manufacturing capabilities are essential, as well as traceability in managing all the parts that go into complicated, multifunction assemblies. It is also important to know which quality standards the supplier uses, as well as any extended services that they offer.

Agility: Finally, it is important to select an RF partner that is operationally and financially strong enough to deliver short-term results, while also being able to withstand turbulence in markets.

LOOKING FORWARD

To adapt to the evolving demands of A&D systems that operate in harsh environments and demand high performance, connector designs are also evolving. These new designs from Times Microwave offer substantial reductions in physical footprint and they are available in single-mount or multiport versions that support the higher connection densities and power thresholds of emerging applications. These designs must also solve the EMI and environmental issues that challenged earlier generations of RF connectors while ushering in a new era of performance in the most demanding, variable and extremely harsh environments. The need to build high performance end products for emerging applications is also fostering an environment where collaborating with an experienced partner with deep engineering expertise and a trusted legacy of development in mission-critical industries has become even more important to ensure the continued superiority of A&D systems. ■

An Embedded Communication System Solution for Operation in the Presence of RF Noise and Interference

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A secure communication system with a spectrum scanning feature is realized with a programmable system-on-chip (PSoC) embedded system platform. The development of this complex electronic system is possible due to the fast data processing and internal signal processing capabilities provided by PSoC controllers. This PSoC-based communication system can operate in an environment with intense channel noise and external disrupting RF signals through the transmission of data packets from different channels whose frequencies change dynamically with time. It enables emergency communication with specialized hardware and a unique algorithm.

When exposed to electromagnetic disturbance, the communication between a transmitter and receiver is interrupted. When a jamming signal is present, a certain region of the electromagnetic spectrum becomes unusable. An emergency communication system is needed when systems such as radio, mobile phone, GPRS, M2M, Bluetooth, Wi-Fi, industrial, scientific and medical (ISM) RF modules and satellite connections, which are today's primary communication tools operating in the UHF band, become unusable due to noise.[1]

The system should incorporate automatic channel scanning, frequency hopping and channel listening with received signal strength indicator (RSSI) information distinguishing between noise and data to provide multi-channel broadcasting and reception. This article describes a secure wireless communication system that can perform automatic channel scanning and channel synchronization to create new communication channels under the influence of electromagnetic noise and interference. It is accomplished with a programmable system platform on a chip.

Several commercial RF receiver, RF transmitter and RF receiver/transmitter modules are examined. The HopeRF RFM22B transceiver module was selected due to its channel selection, frequency hopping, RSSI feedback and multi-channel RF communication capabilities.

The features that enable the design, however, are the algorithm and the capabilities of the embedded system platform. There are several platforms available, including Raspberry Pi,[2] Zynq,[3] Jetson,[4] Altera Cyclone II,[5] Beagle Bone,[6] Odroid,[7] STM32[8] and Cypress PSoC.[9] In this study, the Cypress PSoC is used because it has a CPU core and con-

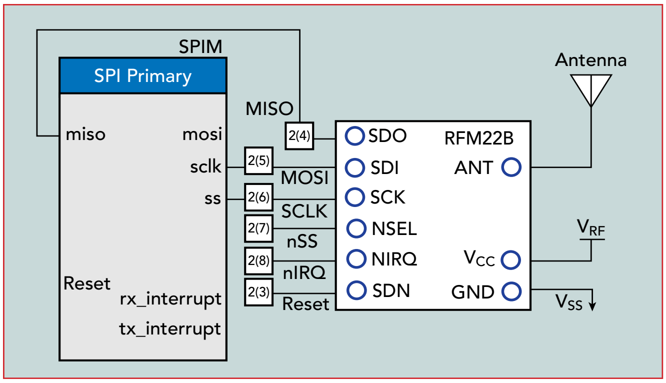

Fig. 1 **SPI connections of RFM22B in the PSoC Creator program.**

figurable analog and digital blocks that differentiate it from traditional microcontrollers. The Cypress PSoC provides ease of use to the designer in the algorithm's implementation, development and debugging phases.

In this design, there is a primary circuit that provides the data to be sent, a secondary circuit that receives the sent data and a noise generator to test the performance of the communication system in the presence of interference. The noise generator acts as a jammer that broadcasts on the desired channel. The primary device ensures that the data entered from the keyboard is transmitted on an empty channel that does not contain noise. The secondary device captures the data synchronously to the channel where the primary device is tuned. Notification that the data has been received is also sent to the primary device. The associated algorithm ensures that the data is transmitted in a safe and secure manner.[10-13]

SYSTEM DESCRIPTION

The RFM22B is a low-cost wireless ISM transceiver module operating in the 240 to 960 MHz range. It consumes 55.5 mW of power in receive mode and 265 mW at maximum output power in the transmit mode. RFM22B communication modules have -121 dBm receive sensitivity and +20 dBm maximum output power. They can provide communication up to very long distances in open space, considering the free space path loss at the operating frequency.

Antenna diversity and frequency hopping support can be used to extend the range and improve performance. Additional system features such as an automatic wake-up timer, low battery detector, 64-byte Tx/Rx-FIFO, automatic packet processing and preamble detection reduce overall power consumption and enable the use of low-cost system MCUs.[14]

The Cypress PSoC comprises a CPU core and configurable analog and digital blocks that differentiate it from traditional microcontrollers. The PSoC and RFM22B modules communicate using the serial peripheral interface (SPI) protocol. SPI connections are shown in ***Figure 1***. The RFM22B receives data from the PSoC through the SCLK, SDI and nSEL pins. The PSoC reads data from the RFM22B transceiver's SDO output pin. PSoC Creator software from Cypress enables the generation of programs for the PSoC 5LP system-on-chip.

The communication protocol is used to write to or read from the registers on the integrated PSoC. The SPI data exchange is as follows:

The 1-bit read-write select bit (R/W) takes place as a 16-bit string, with the following 7 bits of address space and the last 8 bits of data. Here, if the read-write select bit is zero, reading from the 7-bit address is performed, and if it is one, writing to the 7-bit address is performed.

After writing to the desired address, the SS pin drops to zero, the R/W bit is set to one and the desired address is sent in the following 7 bits. The 8-bit data following the address is written to the desired address in this way. Writing is accomplished by transferring a bit on the rising edge of the clock signal.

In the SPI protocol, the SS pin must first drop to zero for data exchange to start, and the secondary must be selected in this way. No data exchange is possible without selecting a secondary. In the read operation, the R/W bit is set to zero and the address is sent in the following 7 bits. The 8-bit data that follows the address is set to zero and filled with the data read from that address. This operation is performed on the rising edge of the clock signal, as in the write operation.

The RFM22B is programmed using the SPI protocol, allowing the use of frequency shift keying (FSK),[15] Gaussian frequency shift keying (GFSK)[16] and on/off keying (OOK)[17] modulation types.

Primary and Secondary Circuit Designs

The embedded system design uses the PSoC 5LP system-on-chip (see ***Figure 2***). In the primary circuit, there is a keyboard for data input, a 2x16 LCD user interface screen, an RFM22B transceiver module and an antenna unit to generate multichannel RF signals. In the secondary circuit, the use of a keyboard is optional; for one-way communication, there is no need for a keyboard.

In the primary circuit, a mini keyboard (cardKB), employing the I^{2}C serial communication protocol, is used to enter data into the system. With dimensions of just 84 × 54 mm, it has 50 keys, 1 neopixel LED, an Atmega328P processor and a communication port. Different characters can be sent using the shift, ctrl, alt, sym and fn keys.

Figure 3 is the corresponding schematic of the primary and secondary circuits with a CY8C5868AXI-LP035 model PSoC. The PSoC is

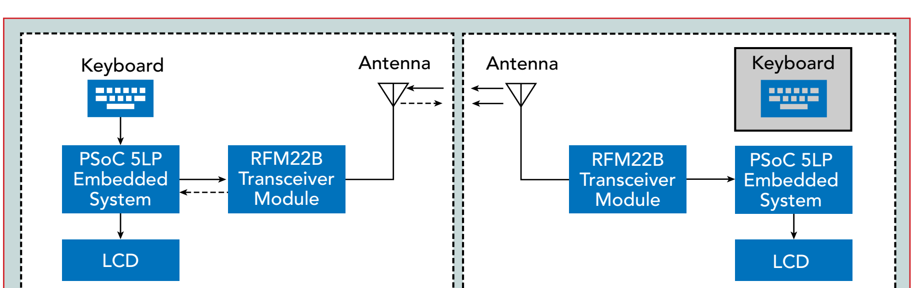

Fig. 2 **Primary and secondary circuit block diagrams.**

packaged in a 100-pin thin quad flat pack clocked by a 24 MHz crystal. Serial wire debug programming outputs are used to facilitate programming operations.

A noise generator circuit enables external parameter adjustment and functions as a jammer for testing as well (see ***Figure 4***). The miniature switch (DIP switch) in the noise generator circuit is used to select the frequency band for noise injection.

The communication system printed circuit boards (PCBs) are shown in ***Figure 5***. The primary and secondary circuit PCBs are in red and the black PCB is the multi-channel RF noise injection circuit.

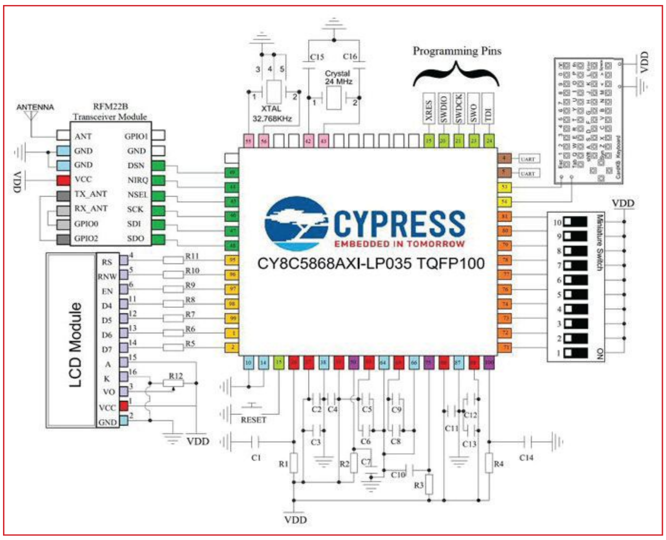

Fig. 3 Primary/secondary circuit diagram.

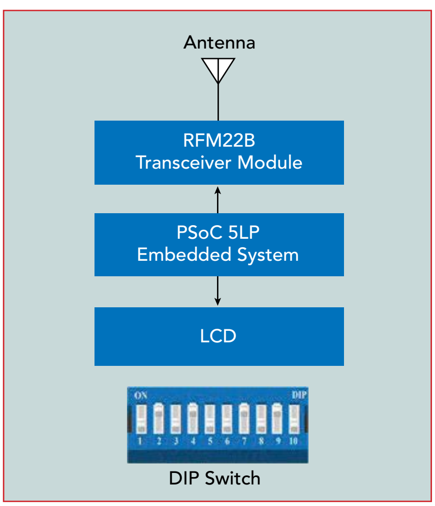

Fig. 4 Noise generator circuit block diagram.

EXPERIMENTAL RESULTS

The setup of ***Figure 6*** is used for system evaluation.

Scenario-1: Transmission of Data Packets from Different Channels in the Presence of Noise

In the first scenario, the dynamic behavior of the system is examined with noise injected in different channels during transmission of the sample message "DATATEST" consisting of eight letters. Each letter of the word "DATATEST" is transmitted at 1-second intervals and there is no noise signal in the environment when the system is energized.

The word "DATA" is sent to the receiver from Channel 1 with a frequency of 300 MHz during a period when there is no noise in the channel. Immediately after, the noise generator is enabled and noise is injected into the 300 to 340 MHz band. The empty channel scanning algorithm starts querying other channels to transmit the remaining part of the data string. Since there is noise in the channels between the frequencies of 300 and 340 MHz, the primary and secondary units on Channel 6 with a frequency of 350 MHz establish a connection and the portion of the data stream "TE" data is sent.

At this time, noise is injected into the 350 to 380 MHz band. Similarly, the channel scanning algorithm establishes a connection on Channel 10 at 390 MHz to send the last two letters of the message, "ST." Thus, the transmission of the data packet, albeit in parts, is accomplished. A screenshot of the spectrum analyzer for Scenario 1 is shown in ***Figure 7***.

Fig. 5 Communication system fabricated PCB assemblies.

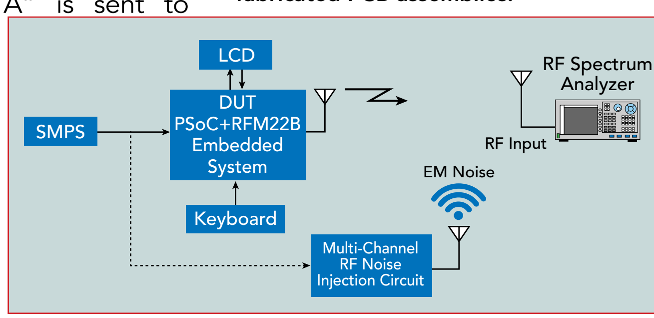

Fig. 6 Test circuit block diagram.

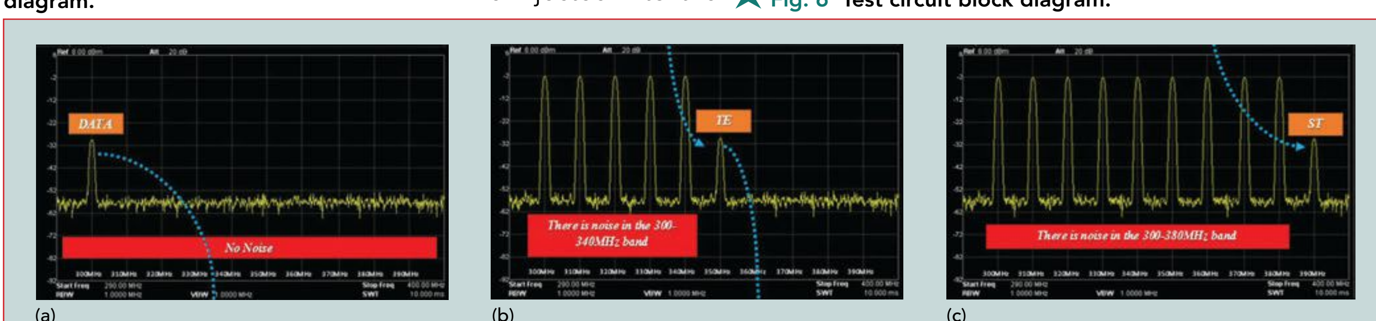

Fig. 7 Automatic channel hopping performance in case of random noise injection: "DATA" sent to receiver from Channel 1 at 300 MHz with no noise in the channel (a), "TE" sent to receiver from Channel 6 at 350 MHz with noise in Channels 1 through 5 (b), "ST" sent to receiver from Channel 10 at 390 MHz with noise in Channels 1 through 9 (c).

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Parameters	Specifications
3GPP Band	n78
DL/UL Frequency	3.55 – 3.7 GHz
Carrier Bandwidth (Max)	100 MHz
Duplex Mode	TDD
Modulation	QPSK/QAM 256/64/16
Sub-Carrier Spacing (SCS)	15, 30 KHz
DC Power @ 296°K	Single
MIMO	64T64R
EIRP	≥ +74dBm (52 dBm + Antenna Gain of 2dBi = 74 dBm)
Effective Isotropic RX Sensitivity	122 dBm

Connectivity Specifications

Parameters	Specifications
Physical	3x 25G Base-T Eth over SFP+
Interface Protocol ORAN Split	7.2x
Time & Synchronization	IEEE 1588v2, IEEE 1914.1, ITU-T G.826x, G.8275.1
Powering	-48 V
Maximum Power	< 900 W

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The channel hopping process successfully transmits the test data in the presence of noise generated in random channels at different times. This is further illustrated in ***Figure 8***.

Scenario-2: Image Transmission with Dynamic Noise Injection

A 5 × 5 pixel grayscale image of the symbol "1" is transmitted (see ***Figure 9a***). Each pixel has a range of 255 hues between black and white. When there is no noise in the environment, it is expected that all data is transmitted on the same channel. However, in the presence of time-varying noise, the data packet may not be transmitted on the same channel entirely, but in parts from different channels.

This information is transmitted on the first channel with a frequency of 300 MHz. When noise is injected into the 300 MHz channel in the t1 to t3 time interval, the gray tone values (25 and 66) of the second and third pixels are transmitted from the second channel at 310 MHz. Due to the randomly varying noise in the t3 to t25 time interval, data is partially transmitted in the most suitable empty channels (see ***Figure 9b***).

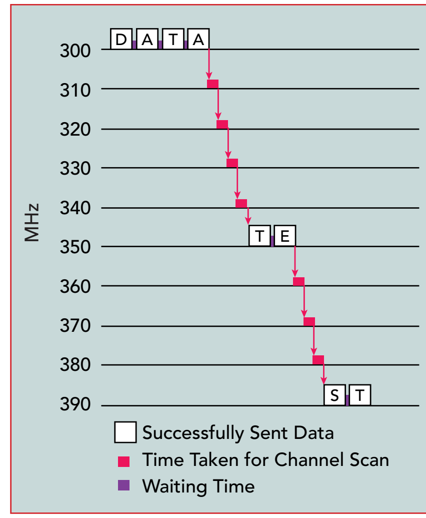


Fig. 8 **Data packet transmission in the presence of noise.**

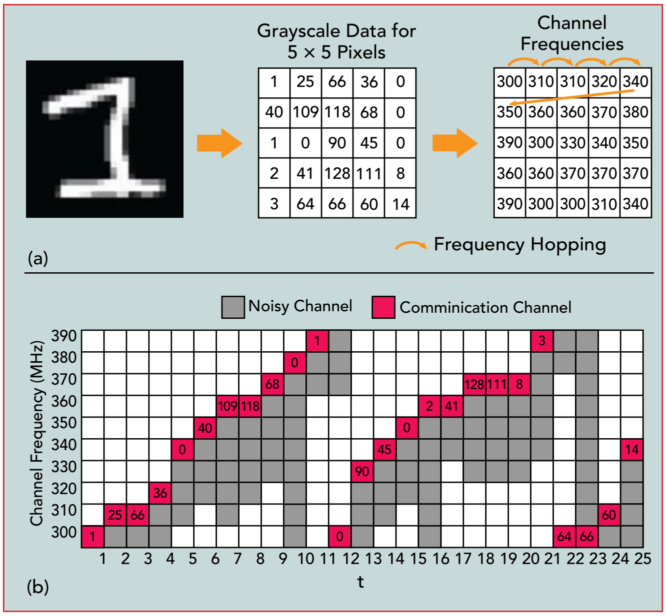
CONCLUSION

A new communication system incorporates a scanning feature realized with a PSoC chip. It changes channels in the presence of noise or interference while maintaining data flow through detected clear channels. Message confirmation algorithms for channel scanning, transmitter-receiver synchronization and successful reception in the developed system are novel.

The HopeRF RFM22B RF transceiver module can work with FSK, GFSK and OOK modulation techniques. It communicates using the SPI serial communication protocol. The PSoC SPI block simplifies the programming of the RF module.

The primary device ensures that the data entered from the keyboard is transmitted through the first noiseless free channel. The secondary device captures the data from the primary device by scanning for free channels.

In a noisy environment, secure RF communication is ensured by circulating between the channels created with the developed algorithms. The primary, secondary and noise generator circuits, for which prototypes are demonstrated, support the frequency range of 240 to 960 MHz (the frequency range of 300 to 400 MHz is used for testing) and a



▲ **Fig. 9** **Time-dependent transmission of image data with dynamic noise injection: image mapping (a) and transmission frequency versus time interval (b).**

general solution is given for a multi-channel system. ■

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Optimization of Surface Acoustic Wave Filter Performance with 2D FEM Simulation and Parametric Variation

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Surface acoustic wave (SAW) filters are widely used in cellular and sensing technologies due to their characteristically compact size and low cost. In this article, the design, in-house fabrication and evaluation of SAW filters are described. The effects of interdigital transducers (IDTs) are investigated by fabricating the SAW devices with various parametric variations, including the presence of reflectors, IDT length, separation of ports, the number of reflectors and the number of IDTs per port. The final, optimized, SAW filter demonstrates less than 3 dB insertion loss with greater than 10 dB return loss at 480 MHz without external matching elements. Compared with other methods, simulation with parametric optimization speeds up the design of SAW devices by reducing optimization time.

SAW filters are widely used in sensing[1,2] and mobile front-end circuits[3,4] due to their compact sizes and high-quality factors.[5,6] Since they share the same fabrication processes with the integrated circuit industry, they can be massively produced at low cost as well.[7]

SAW physics is well-studied and the equations nicely describe the behavior of the filtering response with a simple structure. Traditional modeling approaches include the coupling of modes and the use of Green's functions;[8,9] however, these methods do not depict how detailed design parameters can influence the performance of the filter.

One of the solutions is to use the Finite Element Method (FEM) for handling complex structures. Researchers mainly focus on FEM modal analysis to determine the resonant frequency. However, predicting the frequency response using FEM analysis involves a frequency sweep that requires considerable computational resources. A fully built 3D SAW device requires more than three days for one variation's computation even with a high-end hardware setting.[10]

Simplified 2D FEM models are commonly used for resonant frequency prediction. Then the detailed effects of IDT parametric variation are investigated by in-house fabrication and measurement. This article describes the design, 2D FEM simulation, fabrication and measurement of SAW filters. The resonant frequencies of the filters are estimated by FEM simulation. In-house fabrication and measurement are then carried out to investigate the frequency response and the effect of the variation of design parameters. This simulation method speeds up the design of SAW devices by reducing the optimization time when compared to the 3D method.[10]

SAW FILTER DESIGN PROCESS

SAW Filter Fundamentals

A basic SAW filter has piezoelectric material at its base with IDTs on top. Piezoelectric material induces an electric potential when it undergoes mechanical strain and vice versa. Therefore, the stress-strain relationship and electric displacement-electric potential relationship are coupled together as represented in Equations (1) and (2).[11]

$$D = \left[e\right]\left[S\right] + \left[\varepsilon\right]E \tag{1}$$

$$\left[T\right] = \left[c\right]\left[S\right] + \left[e^{t}\right]E \tag{2}$$

Where:

[D] is the electric charge density displacement
[e] is the piezoelectric coupling coefficient matrix
[S] is the strain matrix
[ε] is the dielectric permittivity matrix
[E] is the electric field
[T] is the stress tensor
[c] is the stiffness matrix
[e^t] is the transpose of the piezoelectric coupling coefficient matrix.

Simulation Method

The commercially available simulation software platform, COMSOL Multiphysics, is used to build the FEM model according to Equations (1) and (2). Structural and electrostatic modules are used since the governing equations involve solid mechanics and electric potential.

3D FEM modeling is more reliable than 2D modeling for investigating the influence of detailed features. However, more than one month is required to solve 10 parametric variations in this 3D model even with a simple hardware configuration.[10] Instead, the 2D one-port FEM model used by previous researchers is modified and extended to a two-port configuration for analysis.[12]

The extended 2D model is chosen over the 3D model to predict the resonant frequency for the SAW filter, which is the most important filter parameter. Simulation time is significantly reduced, and the passband frequency response can be roughly estimated.

The minimum pitch of IDTs fabricated by in-house facilities is 2 μm. As a result, a resonant frequency of around 440 MHz is selected for simulation to satisfy this minimum feature size, and the resonant frequency is also expected to drift slightly. The 2D simulation is easily accomplished within a few minutes (versus several days for a 3D simulation) on a general-purpose laptop computer equipped with an Intel i5 2.4 GHz CPU and 4 GB RAM.

Parameter Variation

First, a filter with a frequency around 440 MHz is simulated (see ***Figure 1***). Multiple design variations are then fabricated and investigated. Different parametric variations are listed in ***Table 1*** and ***Figure 2*** shows the 2D structure of the SAW filter with its design parameters. The five selected features are chosen because their impacts on the SAW filter frequency response are relatively vague from the governing equations. Pitch, for example, was not selected as its impact is well-studied and significantly dominates the resonant frequency.

The first parameter is the presence of the reflector. The reflector comprises a series of connected metal grids with the same pitch as the IDT. Reflectors redirect emitted waves to the receiving port by reflecting or absorbing the incoming waves, so a filter equipped with reflectors is expected to perform better. The second parameter is the length of IDT overlap. Overlaps of 20, 100, and 200 μm of are selected for fabrication. An inefficient overlap deteriorates bandpass performance and excessive length wastes wafer area. The third and fourth parameters are the number of IDTs per port (N) and the number of reflectors per port (M), respectively; 10, 20, 40 and 80 pairs of N or M are selected. The last parameter is the separation of the two ports; 100, 200, 400, and 800 μm of separation are used. A shorter separation is expected to have less loss.

All variations are expected to affect the resonant frequency and bandwidth slightly, but the effects from variation of these five parameters are expected to be significantly less than the pitch. When the pitch size is fixed by the fabrication technique, however, tuning the other design parameters becomes important. The values shown in bold text in Table 1 are used when the other features are varied. For example, when the length of IDT overlap is varied from 20 to 200 μm, all the SAW filters have reflectors, 40 IDTs per port, 40 reflectors per port and 200 μm separation between the two ports.

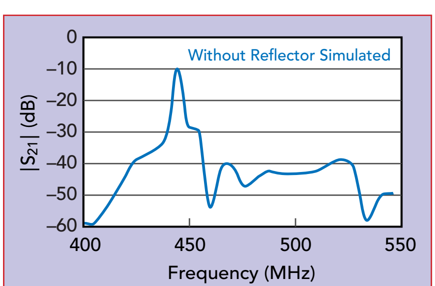

Fig. 1 Simulated frequency response of the 2D model.

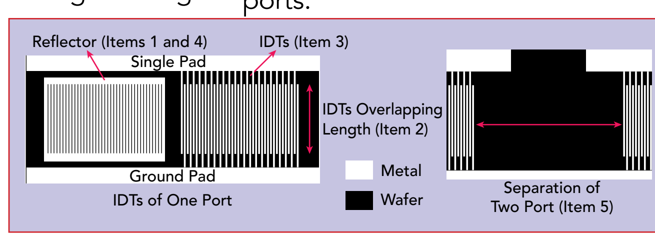

Fig. 2 Design parameters.

TABLE 1
PARAMETRIC VARIATIONS

Item	Parameter	Variation
1	Presence of Reflector	**With**/Without
2	Length of IDT Overlap (μm)	20/**100**/200
3	Number of IDTs Per Port (N)	10/20/**40**/80
4	Number of Reflectors Per Port (M)	10/20/**40**/80
5	Separation of Ports (μm)	100/**200**/400/800

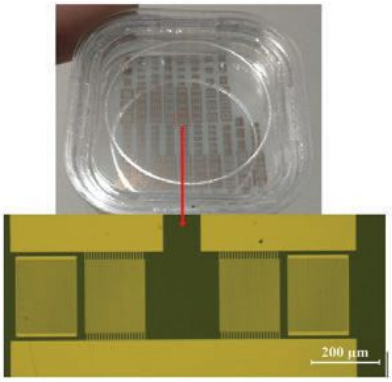

Fig. 3 Fabricated SAW filters.

FABRICATION

All SAW filter variations are fabricated on a wafer from one mask. ***Figure 3*** shows photos of the wafer and the pattern of fabricated filters. A 128-degree Y-cut LiNbO3 wafer is chosen because of its large piezoelectric coupling coefficient. First, the wafer is spin-coated with an AZ 5214E photoresist. Then, the pattern mask is mounted on the spin-coated wafer with a soft contact and exposed to UV light. Polymerization of the photoresist layer by the UV light decreases its solubility so that after washing, only the UV-exposed photoresist is left on the wafer.

The wafer with patterned photoresist is transferred to the sputtering system where 20 nm of silver and 180 nm of copper are uniformly sputtered onto the wafer disregarding the existence of the photoresist layer. The silver layer increases the adhesion of the copper.

Finally, the sputtered wafer is soaked in acetone. The photoresist layer is removed together with the metal layer from its top so that the wafer with the desired pattern remains.

The fabrication process is illustrated in ***Figure 4***.

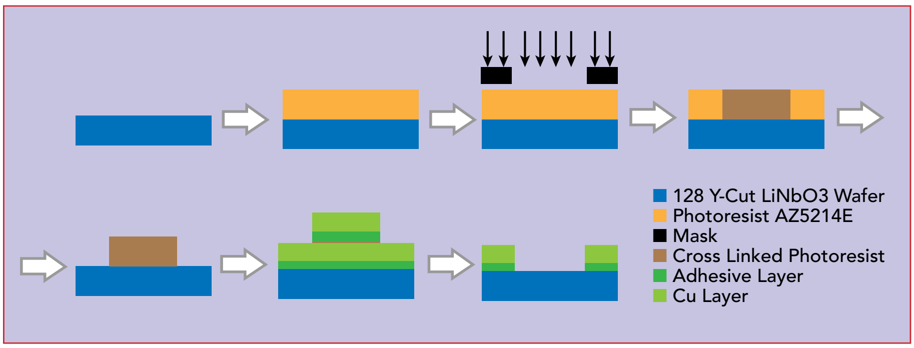

Fig. 4 SAW filter fabrication process.

EXPERIMENTAL RESULTS

Figure 5 shows a filter being measured at the probe station. S-parameters (S_{11} and S_{21}) are measured with a vector network analyzer.

The impact of the reflectors can be observed in ***Figure 6***, where the filter with reflectors displays significantly better transmission performance. The filter with reflectors

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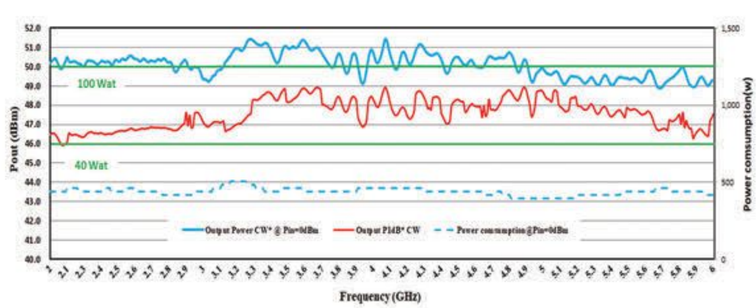
- **Low Spurious** -70 dBc (Typ.)
- **Low VSWR** 1.5:1 (Typ.)
- **High Efficiency** 20% (Typ.)

MPAR-020060S50 is a 2~6GHz 100W GaN amplifier with state-of-the-art GaN design technology. It has higher saturation output power while keeping higher P1dB and better linearity.

The built-in control, monitoring and protection functions are offered. It is designed for high power CW & pulse system applications, such as 5G, LTE, WIFI and other related system module & EMC test.

★ Custom designs are available



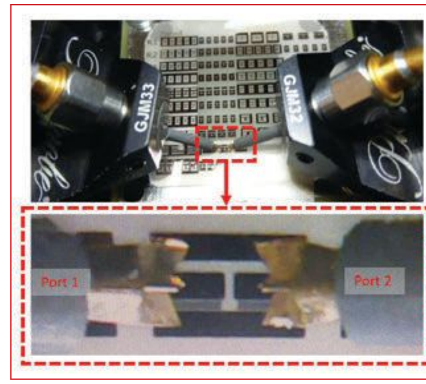
Pout@ Pin=0dBm & P1dB (CW, Load VSWR≤1.2, 25℃)

More Information-
Scan the QR Code

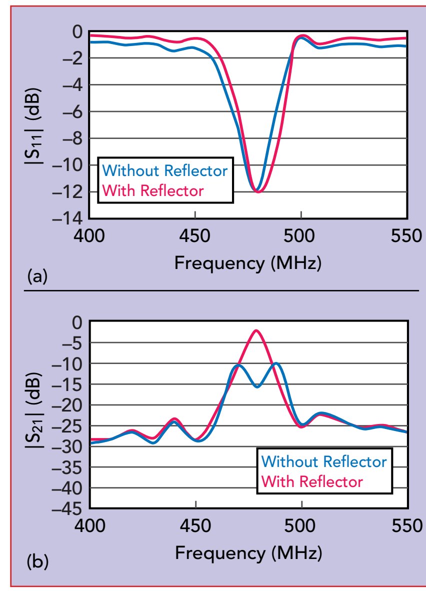
MIcable Inc.

www.micable.cn sales@micable.cn +86-591-87382856

has a higher $|S_{21}|$ (about -3 dB) at the resonance peak, while without reflectors it is less than -10 dB around the peak. In Figure 6a, $|S_{11}|$ of both designs is almost identical. Therefore, it can be concluded that the difference in $|S_{21}|$ depends to a greater degree on reception versus transmission. The induced mechanical waves are reflected between the two ports by the reflectors so that the same wave is transmitted to the receive port multiple times. Therefore, the filter with reflectors provides better performance.

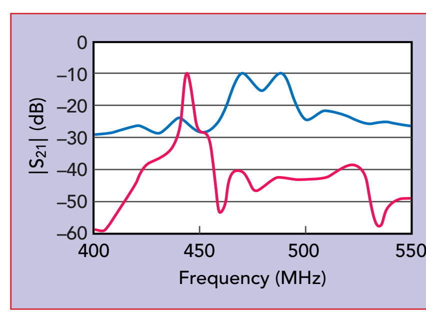


▲ Fig. 5 Probe station measurement.



▲ Fig. 6 Impact of reflectors on filter performance: measured reflection coefficient $|S_{11}|$ (a) and transmission coefficient $|S_{21}|$ (b) with and without reflectors.

Measured and simulated $|S_{21}|$ of the SAW filter without reflectors are shown in ***Figure 7***. The resonant frequency is shifted from 440 MHz in the simulation to 480 MHz in the measurement. The difference is attributed to the simplified 2D modeling approach of the 3D structure. However, it does provide a close prediction of $|S_{21}|$.



▲ Fig. 7 Comparison of measured (blue line) and simulated (red line) $|S_{21}|$ of a saw filter without reflectors.

Figure 8 shows the results of the remainder of the parametric study. Figure 8a compares $|S_{21}|$ of filters with different IDT overlapping lengths. A length of 20 μm is insufficient to fully activate electromechanical coupling, while 100 and 200 μm are sufficient. The measurement of lengths between 20 and 80 μm will be needed if a minimal design is desired; however, a 200 μm overlapping length shows only a slight shift in the resonance peak and broadens the bandwidth.

Figure 8b illustrates the impact of port separation on $|S_{21}|$. Greater attenuation is expected with increasing separation. The filter with 800 μm in separation has about 3 dB greater attenuation than those with 100 and 200 μm. As the separation is increased to 800 μm, a wider bandwidth and a shift in the resonance peak is observed.

Both the numbers of IDTs (N) and reflectors (M) are varied independently (see Figures 8c and 8d). The number of reflectors per port is fixed to 40 when varying the number of IDTs per port and vice versa. The best performance ($|S_{21}|$ less than -3 dB) is achieved when M = 10 or 40. When M = 80, the peak value of $|S_{21}|$ drops to -10 dB. This implies that fewer reflectors are needed to effectively reflect the incident mechanical waves. An excessive number of reflectors or non-unity ratio between IDTs and reflectors appears to deteriorate performance.

The best performing SAW filter is one with 40 pairs of reflectors and IDTs per port, greater than 100 μm in IDT length and 100 μm or less of port separation. It demonstrates less than 3 dB of insertion loss and greater than 10 dB of return loss at 480 MHz without external matching elements at the ports (see ***Figure 9***).

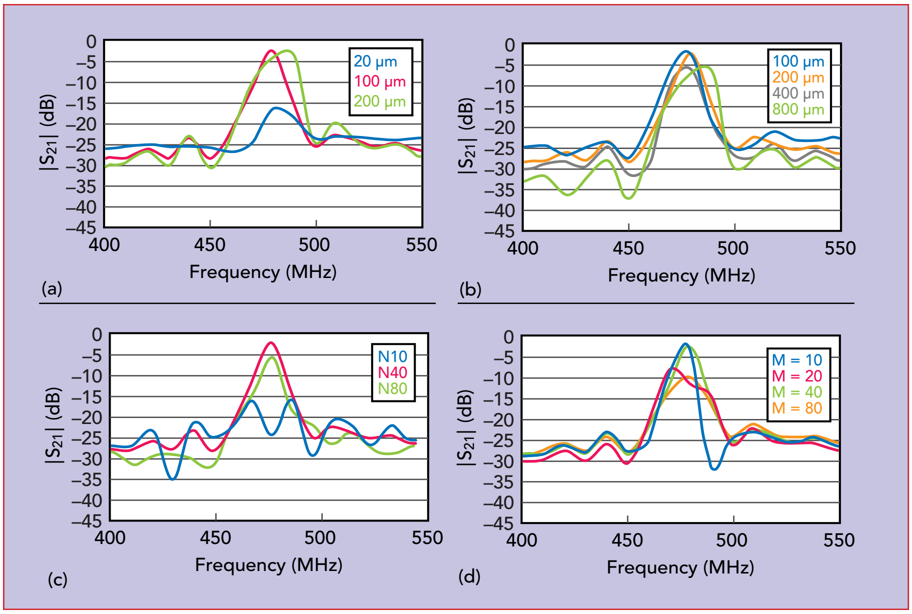
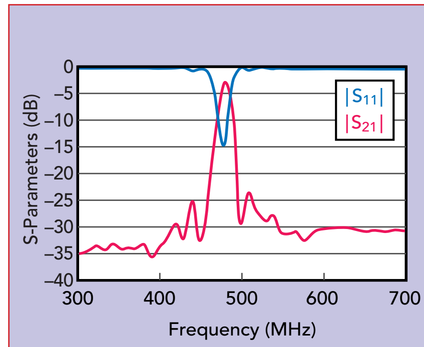


Fig. 8 **Transmission coefficient $|S_{21}|$ as a function of IDT overlap (a), port separation (b), number of IDTs per port (c) and number of reflectors per port (d).**

CONCLUSION

The investigation of the impact of SAW features on performance is demonstrated through an in-house fabrication capability to manipulate detailed features with a short design-fabrication-measurement-redesign cycle. An entire design-fabrication-measurement procedure is established and serves as a foundation to meet future requirements for sensing and telecommunication components.



▲ Fig. 9 **Measured $|S_{11}|$ and $|S_{21}|$ of the optimized filter.**

ACKNOWLEDGMENT

This work was supported by the Internal Research Grant and The Dean's Research Fund of the Faculty of Liberal Arts and Social Sciences from the Education University of Hong Kong (Project No: R4348 and FLASS 04717) and an IEEE-MTTS undergraduate scholarship. The fabrication facilities were provided by the University Research Facility at The Hong Kong Polytechnic University (PolyU). The measurements were carried out of Dr. Mung's laboratory. ■

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RF-over-Fiber Solutions for EW Applications

PPM Systems
Swindon, U.K.

RF-over-fiber is emerging as a technology that has the potential to revolutionize the way we transmit and receive RF signals. This solution provides benefits in industry applications ranging from telecommunications and defense to broadcasting and research. PPM Systems has developed an RF-over-fiber-enabled electronic support measure (ESM) system and has been instrumental in advancing this technology. ***Figure 1*** shows electronic warfare (EW)-equipped military vehicles.

RF-over-fiber is a communication technology that leverages the properties of optical fibers to transmit RF signals over long distances. The technology relies on converting RF signals into optical signals that are transmitted through optical fibers and then converted back into RF signals at the receiving end. This process offers several advantages over traditional RF transmission methods, making it a preferred choice in numerous applications.

Fig. 1 **Typical military application.**

Some of these advantages include:

Low Signal Loss: RF-over-fiber minimizes signal loss, ensuring signal quality over extended distances. This is crucial in applications where signal fidelity is of paramount importance, such as in military communications and satellite links.

Immunity to Electromagnetic Interference: Optical fibers are immune to electromagnetic interference, unlike traditional coaxial cables. This property is especially vital in critical applications like radar systems, where any interference can have dire consequences.

Long-Distance Transmission: Optical fibers can transmit RF signals over much longer distances than traditional copper cables. This extended reach is vital in applications like telecommunication networks and remote sensing.

Security and Signal Integrity: RF-over-fiber provides enhanced security since it is difficult to tap or intercept optical signals.

Fig. 2 Antenna close coupled unit.

Fig. 3 Antenna power control unit.

Fig. 4 Radio interface unit.

This is crucial in secure communications and military applications.

Reduced Size and Weight: The use of optical fibers can decouple components within RF systems, enabling lightweight more man-portable subsystems suitable for applications like remote sensing equipment.

RF-over-fiber has found its way into a multitude of applications, each benefiting from its unique advantages. In the telecommunications industry, RF-over-fiber is utilized to transmit signals between cell towers, data centers and central offices. The signal characteristics help enable reliable network connectivity. In broadcasting applications, TV and radio broadcasters use RF-over-fiber to transmit high-quality signals from remote locations to broadcasting studios. This technology ensures that the signal remains pristine over long distances, which is critical in delivering high-definition content to viewers.

In the aerospace and defense sector, RF-over-fiber is extensively used in radar systems, EW and secure communications applications. The immunity to electromagnetic interference and long-distance transmission capabilities of the technology are advantageous in these applications. In satellite communications applications, this technology is used to transmit signals from ground stations to satellites in orbit. The low signal loss of RF-over-fiber helps to close the link budget to maintain communication links with the satellite. There are also applications in the instrumentation, oil and gas, along with the transportation and traffic management industries.

PPM Systems is a recognized leader in RF-over-fiber technology and has been at the forefront of innovation in this field. The company has contributed significantly to the development and implementation of RF-over-fiber solutions, continually pushing the boundaries of what this technology can achieve. PPM offers a range of RF-over-fiber products that include transceivers, amplifiers, antennas and signal processing equipment. These products are designed to meet the unique requirements of various applications, ensuring reliable and high performance RF-over-fiber solutions.

PPM has released an RF-over-fiber ESM system based on its commercial off-the-shelf (COTS) products. ***Figure 2*** shows the antenna close coupled unit (CCU). This unit is typically installed with the power control unit (PCU) shown in ***Figure 3*** and the radio interface unit (RIU) shown in ***Figure 4***.

The antenna CCU receives RF signals and converts them from electrical to optical signals for distribution to the RIU. The antenna mounting of the CCU minimizes signal loss and electromagnetic disturbances to maximize signal fidelity. There are two optical outputs for a low band of 10 MHz to 6 GHz and a high band of 1 to 18 GHz, which are combined into a single fiber-optic cable.

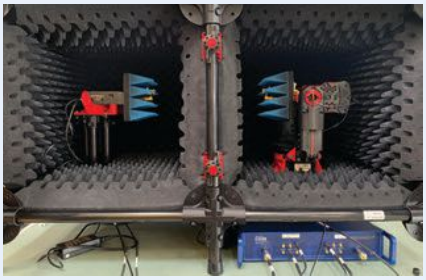
The antenna PCU is typically installed with the antenna CCU. The enclosure provides the power supply and control functionality, converting the main power supply to DC power for the antenna CCU. The PCU also contains a manual switch to bypass the low noise amplifiers in the antenna for sensitivity tuning.

The RIU ties the system together. It has open standards embedded at the core to convert the signal from the optical to the electrical domain, process it and securely distribute any signal anywhere. The RIU operates from 10 MHz to 18 GHz in two bands.

While this product suite is intended for COTS solutions, PPM Systems understands that different industries have specific needs. Custom solutions cater to the unique requirements of customers, guaranteeing that their systems are optimized for maximum efficiency. Through research and development (R&D) activities, PPM Systems continues to invest to stay at the forefront of RF-over-fiber technology. This commitment to innovation ensures that its products are always on the cutting edge.

PPM Systems also offers comprehensive customer support, including system design, commissioning and maintenance. The experts are available to assist customers in achieving the best possible results from these RF-over-fiber solutions. As this technology continues to evolve, it will become a cornerstone in commercial and defense systems. PPM's commitment to quality, ongoing R&D and customized solutions ensures that the company remains a trusted partner and enabler for businesses and organizations seeking to harness the full potential of RF-over-fiber technology.

PPM Systems
Swindon, U.K.
ppmsystems.com



Understanding D-Band OTA Measurement Distances

Many factors influence measurement accuracy for antenna patterns and radiated power levels in over-the-air (OTA) test systems. A primary consideration is the distance between the measurement probe and the radiating device or antenna under test (AUT). In typical measurement systems, each device should be outside the near-field and Fresnel regions of the other device. Equivalently, the probe and the AUT should be within each other's far-zone regions. The distance to this region is often estimated as $2D^2/\lambda$ where D is the diameter or length of the antenna and λ is the operating wavelength. In a compact range, where a parabolic reflector projects a plane wave onto the AUT, the separation distance can be much smaller.

In directional antennas, the effective aperture area, A_e, is computed as $\lambda^2G/4\pi$ where G is the antenna gain. If a directional antenna's effective aperture area is approximated as a circle with diameter D, the far-zone distance is estimated as $2\lambda G/\pi$, where G is the antenna gain expressed as a power ratio. For D-Band measurements, the far-zone distance from an antenna with 20 dBi gain is approximately 17 cm at 110 GHz and 11 cm at 170 GHz. If the measurement probe and the AUT have similar levels of gain, the separation distance should be at least twice these values. A test system with a 77 cm separation between the probe and the AUT easily meets the spacing requirements typically encountered for D-Band measurements.

New developments in small-profile transmit/receive frequency extenders for vector network analyzers (VNAs) are complemented by a wider range of choices for measurement enclosures, VNAs, robotic positioning systems and phase-stable coaxial cables. When evaluating any OTA measurement system, start by comparing the far-zone distances required for accurate test results to the measurement distances provided.

VENDORVIEW

Eravant
Torrance, Calif.
www.eravant.com

Millimeter Wave Amplifier for 5G FR2

The Spacek Labs Model SLKaQ-38-15 amplifier operates from 26.5 to 50 GHz, making it suitable for 5G FR2 applications. The amplifier has a noise figure of 3.8 dB, output P1dB of 15 dBm typical, along with 38 dB minimum and 43 dB typical gain. The VSWR is 1.5:1 typical, using 2.4 mm connectors. The bias voltage for this amplifier is +8 to +12 VDC at 0.3 A. Without a heat sink, the amplifier measures 1.13 x 0.93 x 0.31 in. Spacek Labs offers both custom and standard amplifier designs in the 10 to 110 GHz frequency range. The modular amplifier designs allow a large variety of configurations to meet your specific requirements. For a more customized solution, our engineers and in-house CNC machining facility can produce an amplifier design to meet your specific needs.

Spacek Labs is a small, woman-owned business that designs and manufactures mmWave and microwave components and subsystems operating from 10 to 110 GHz. Since 1982, Spacek Labs has been providing products to government agencies, universities, research institutions and private industry. Spacek Labs operates from two adjacent facilities occupying 10,000 square feet. Except for shock and vibration testing equipment, Spacek Labs owns all the necessary manufacturing, test and screening equipment to support its 2 to 110 GHz product portfolio. The company has a Faraday cage screen room for low noise testing, along with the capability to temperature test its devices from -55°C to +165°C. Spacek Labs also has in-house cryogenic test facilities capable of temperatures as low as 15 Kelvin.

Spacek Labs
Santa Barbara, Calif.
www.spaceklabs.com

100 GHz Pulse Inverter Operates Over Nearly Six Decades of Bandwidth

HYPERLABS INC. is expanding its 100 GHz component offerings by introducing the HL9419 pulse inverter. The 3 dB points of this device occur at 150 kHz and 100 GHz, meaning the operating range of the HL9419 spans close to six decades of bandwidth. The HL9419's flat frequency response translates into an excellent inversion of time-domain signals. This performance makes the device well-suited for inverting a wide range of ultra-wideband, noise-like pulses and radar pulse waveforms, as well as high speed serial data signals up to 112 Gbaud.

Using HYPERLABS' proprietary materials and manufacturing techniques, the HL9419 achieves this bandwidth performance in a standard housing measuring 2.4 in. x 0.8 in. x 0.4 in. featuring 1.0 mm connectors. HYPERLABS also offers a 67 GHz version of the pulse inverter, P/N HL9417, which utilizes 1.85 mm connectors. Both products come standard with a jack/plug configuration. Alternate connector configurations and connector series are available upon request.

At its core, the HL9419 pulse inverter is a cross-connection between the coaxial center conductor and the coaxial outer conductor ground. This cross-connection results in a DC short circuit to ground on the RF input and output. Careful selection and placement of proprietary microwave absorber and ferrite material extends the operation of this inverter to low frequencies.

Founded in 1992 and privately owned, HYPERLABS sells an array of broadband components. These include baluns, bias tees, DC blocks, power splitters/dividers, attenuators, transition time converters and pick-off tees, operating up to and above 100 GHz. The HYPERLABS instrumentation line includes pulse generators, TDRs/TDTs, controlled impedance analyzers, signal path analyzers, cable skew testers and samplers/harmonic down-converters.

VENDORVIEW

HYPERLABS INC.
Beaverton, Ore.
www.hyperlabs.com

Flexible Cables Reduce Cost

HASCO Littlebend cables play an integral role in RF, microwave and mmWave system integration and box builds. They are extending their usefulness to 6G and 5G MIMO systems. These versatile cables are used in antenna OTA testing, switch and attenuator matrices, in-box connections and board-to-board connections. In applications requiring precision and reliability, Littlebend cables deliver.

The standout feature of these cables is their flexibility. They can navigate intricate pathways within confined spaces while preserving signal integrity. This flexibility means Littlebend cables are highly suited for internal connections, particularly within confined spaces where traditional right-angle connections might prove unwieldy. This is invaluable in MIMO systems that contain multiple antennas and transceivers. HASCO's Littlebend cables can reduce costs by eliminating the need for expensive right-angle adapters and swept connectors while also enabling space savings.

These cable assemblies are commensurate with Huber+Suhner's Minibend-L™ low loss cables. They feature high tensile-strength stainless steel braids that enhance their durability and overall performance. With a cable outer diameter of 2.64 mm and a bending radius of less than 5 mm, these cables are suited for applications with spatial constraints and intricate routing needs.

The connector design is characterized by a compact structure and a retention force exceeding 90 N, eliminating the need for right-angle connectors. Instead, the cable assembly can be vertically bent at the root of the connector joint. This results in a reduced height after bending when compared to a regular right-angle adapter or swept connector.

Littlebend Ultra-Flexible Cables are 100 percent tested for VSWR and insertion loss and they are available in standard lengths from 3 to 48 in.

VENDORVIEW

HASCO, Inc.
Moorpark, Calif.
hasco-inc.com/Littlebend

Infineon Opens New Lab

Infineon has opened a new laboratory for the development of quantum electronics in Oberhaching, near Munich. The objective is to develop and test microelectronic circuits for quantum computers that will be stable and small, will operate reliably and can be produced on an industrial scale.

Infineon Technologies AG
www.infineon.com

Overcoming Barriers to 5G Private Networks

The All Things 5G podcast talks with Puneet Sethi of Ataya, Richard Piasentin of Accedian Networks and Jagadeesh Dantuluri of Keysight to find out about the latest implementations of 5G private networks, what industry verticals are leading the way and the hurdles being encountered (and overcome).

Keysight Technologies
https://bit.ly/3Qv8Zsa

KVG Presents New Website

KVG launched their new website on 1 September, presenting their highly stable products with the best phase noise on the market. Visit the new website and learn more about KVG and their products.

KVG Quartz Crystal Technology GmbH
www.kvg-gmbh.com

mmTron Moves to New Office

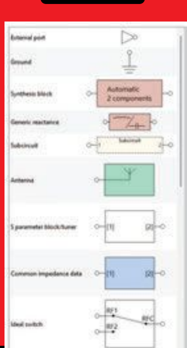
To support the market's interest in their mmWave products, mmTron moved into larger offices. The new space has an expanded lab for development and production testing.

mmTron, Inc.
https://mmtron.com

Optenni Unveils New Schematic Entry Environment

Optenni Ltd. announced a major update of Optenni Lab, a circuit synthesis software tailored for antenna and RF front-end design engineers. The new Optenni Lab version 6.0 offers a unique RF circuit design environment with fully integrated circuit synthesis capabilities and optimization of antenna and radiation characteristics.

Optenni Ltd.
www.optenni.com



Samtec Solderless Compression Mount eBrochure

Samtec has fully released its line of vertical solderless, compression mount connectors that incorporate precision alignment feature. A brief technical overview, along with board thickness and torque specifications, is available in the eBrochure.

Samtec
samtec.com/solderless-compression

NEW PRODUCTS

FOR MORE NEW PRODUCTS, VISIT WWW.MWJOURNAL.COM/BUYERSGUIDE
FEATURING VENDORVIEW STOREFRONTS

DEVICES/ COMPONENTS/MODULES

Ka-Band Transmitter Module

VENDORVIEW

Providing +50 dBm equivalent isotropic radiated power at 26.8 GHz, model SSK-ST2730253027-28-C1 is a compact Ka-Band transmitter module designed for small satellites. The space qualified transmitter includes a phase-locked local oscillator, an up-converter and an integrated lens-corrected antenna that provides 23 dBi gain with circular polarization. The transmit power is +29 dBm with harmonic suppression of 50 dBc and spurious outputs below -60 dBc. The supply voltage is +8.0 VDC at 1.5 amps.

Eravant
www.eravant.com

Narrowband Bandstop Filter

VENDORVIEW

WR19 bandstop filter with 10 dB notch between 50.265 to 50.34 GHz. Exceed Microwave can design bandstop filters at different frequencies, notch depth and bandwidths. Exceed Microwave designs and produces various types of custom RF/ microwave filters, designed and manufactured in the U.S. AS9100D/ISO9001:2015 certified. ITAR Registered.

Exceed Microwave
www.exceedmicrowave.com

Multilayer Organic Filter

KYOCERA AVX offers three multilayer organic (MLO) filter series that are both designed and field proven to deliver best-in-class performance in a variety of RF applications. The LP Series MLO lowpass, HF Series MLO highpass and BP Series MLO bandpass filters are low-profile passive devices based on KYOCERA AVX's patented MLO high-density interconnect technology. This technology has a high dielectric constant and high lot-to-lot repeatability and exhibits low material losses, which enables the development of high Q passive printed elements, such as inductors and capacitors, in a multilayer stack.

KYOCERA AVX
www.kyocera-avx.com

6 to 40 GHz, 5-Way Power Divider Combiner

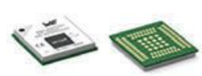
VENDORVIEW

MIcable 6 to 40 GHz 5-way ultra-wideband power divider/ combiner can accept a 6 to 40 GHz signal and deliver five output signals with equal amplitude and phase. Due to extremely wide bandwidth, excellent VSWR, insertion loss and isolation, it can be widely applied in 5G, testing, instrumentation and other fields.

MIcable Inc.
www.micable.cn

Cellular Module for IoT Applications

VENDORVIEW



Würth Elektronik presents the Adrastea-I, its high performance, ultra-low power consumption, multiband LTE-M and NB-IoT module. This cellular module, measuring only 13.4 × 14.6 × 1.85 mm, comes with integrated GNSS, integrated ARM Cortex M4 and 1 MB Flash reserved for user application development. The module is based on the high performance Sony Altair ALT1250 chipset. Certified by Deutsche Telekom, the Adrastea-I module enables quick integration into end-products without additional labels, industry-specific certifications (GCF) and operator approvals needed, whenever Deutsche Telekom IoT connectivity (SIM card) is used.

Würth Elektronik
www.we-online.com

CABLES & CONNECTORS

Compression-Mount Connectors

Samtec has released its new line of vertical solderless, compression-mount connectors with precision alignment features. Spanning DC to 90 GHz, the new connectors are well suited for use in high frequency test and measurement applications and are available in full production quantities. The connectors come standard with precision alignment features that are exclusive to Samtec and ensure peak connector performance. The solderless launch allows for easy, field-replaceable, cost-effective assembly of the PCB and eliminates possible performance degradation commonly found with solder reflow.

Samtec
www.samtec.com

AMPLIFIERS

AMP2080E, 10 kHz to 250 MHz, 1250 W

VENDORVIEW

Exodus AMP2080E-LC is ideal for broadband EMI-Lab applications. The Class A/AB linear design is for all modulations and industry standards. Covering 10 kHz to 250 MHz, it produces 1250 W minimum with 62 dB minimum gain. The device has excellent flatness, optional monitoring parameters for forward/reflected power indication in watts and dBm, VSWR, voltage, current and temperature sensing for superb reliability and ruggedness. It has a cabinet integrated 18U and weighs approximately 120 kg.

Exodus Advanced Communications
www.exoduscomm.com

MMIC Amplifier

VENDORVIEW

Mini-Circuits' model LVA-273PN+ is a wideband GaAs HBT MMIC amplifier with > 17 dB gain from 10 MHz to 26.5 GHz. With low additive phase noise of typically 172 dBc/Hz offset 10 kHz from the carrier, it delivers typical output power at 1 dB compression of +18.3 dBm at 10 GHz and +16.1 dBm at 20 GHz. The 50 Ω amplifier draws 85 mA at +5 VDC and is supplied in a 4 × 4 mm 24-lead QFN-style package.

Mini-Circuits
www.minicircuits.com

Power Amplifier MMIC

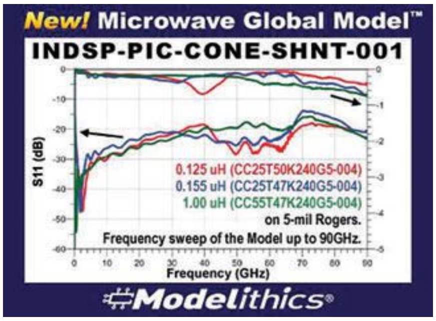
mmTron Inc. announced the highest efficiency class AB GaN power amplifier MMIC for the 17.3 to 21.2 GHz satellite downlink band. Available as a die for assembly in multi-chip modules or in a surface-mount package, the TMC261 covers 17.3 to 21.2 GHz with margin and provides 1.1 W of output power with 35 percent power-added efficiency at a noise power ratio of 13 dB. The three-stage MMIC provides 31 dBm output power at 1 dB compression and has 24 dB linear gain.

mmTron Inc.
www.mmtron.com

NewProducts

SOFTWARE

90 GHz S-Parameter Data Model



Modelithics has introduced a new part-value selectable S-parameter-based model of the Piconics -004 Series Broadband Conical Inductors: CC25T50K240G5-004 (0.125 µH), CC25T47K240G5-004 (0.155 uH) and CC55T47K240G5-004 (1.00 µH) in shunt-mount configuration. The model, included within the latest release of the Modelithics COMPLETE Library, is broadband validated through 90 GHz. Piconics is sponsoring free 90-day trials of all available Modelithics Piconics models.

Modelithics
www.Modelithics.com/MVP/Piconics

SOURCES

Dielectric Resonator Oscillators

VENDORVIEW

Quantic PMI Model PDRO-6800M-13DBM-SFF is a dielectric resonator oscillator with an output frequency of 6800 MHz and a minimum output level of +13 dBm. It has a reference frequency of 0.1 GHz, an input level of 3 to 13 dBm, an output level of 15.1 dBm, spurious of 89.5 dBc and harmonics of 30.6 dBc. This model size is 2.25 × 2.25 × 0.62 in. and has SMA female connectors.

Quantic PMI
www.quanticpmi.com

ANTENNAS

Quad-Ridge, Dual Polarized, Broadband Gain Horns

VENDORVIEW

Fairview Microwave launched its product line of quad-ridge, dual polarized, broadband gain horns. These gain horns range from 0.8 GHz to 95 GHz waveguide and are available in gain varieties of 6, 10, 12, 15 and 20 dBi. Designed to perform in broadband test and measurement applications, these gain horns are instrumental in characterizing antennas and wireless systems.

Fairview Microwave
www.fairviewmicrowave.com

Cutting-Edge IoT Multiband Antennas

VENDORVIEW

Pasternack introduces its state-of-the-art IoT multiband combination antennas. Designed for vehicles, fleets and pivotal base stations, these multiband antennas are set to revolutionize how industries perceive and utilize mobile connectivity. The latest from Pasternack's innovation lab integrates the potency of 4G, 5G, Wi-Fi and GPS bands within a singular, sleek radome. This harmonious fusion ensures that emergency teams, on-the-move fleets and first responders can guarantee an unwavering link, no matter where duty calls.

Pasternack
www.pasternack.com

TEST & MEASUREMENT

MXO 5 Next-Generation Oscilloscopes

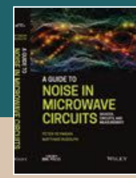
VENDORVIEW

Rohde & Schwarz presents its new R&S MXO 5 oscilloscopes, available with four or eight channels. Building on next-generation MXO-EP processing ASIC technology developed by Rohde & Schwarz and introduced with the R&S MXO 4, the new eight-channel R&S MXO 5 oscilloscopes take measurement performance to the next level.

Rohde & Schwarz
www.rohde-schwarz.com

MICRO-ADS

Reviewed by: Doug Jorgesen



Bookend

A Guide to Noise in Microwave Circuits

By Peter Heymann and Matthias Rudolph

A Guide to Noise in Microwave Circuits is a comprehensive treatment of noise in microwave circuits. The authors, Peter Heymann and Matthias Rudolph, are both researchers with a long history of publishing on the topics of noise and microwave circuits. The book begins with a general introduction to noise in electronic circuits, followed by a more detailed discussion of the various sources of noise in microwave circuits. The authors then cover the treatment of noise in linear and nonlinear networks, as well as the noise of common microwave devices such as diodes, bipolar transistors, operational amplifiers and field-effect transistors.

The most practical section of the book is the chapter on noise measurement. In this chapter, the authors address some of the more challenging problems in noise measurement, including noise measurement of transistors using load-pull and noise measurement in fixtured and on-wafer situations. The authors also discuss accuracy and error estimations, which are particularly important for noise measurements. The final section of the book is devoted to phase noise. The authors cover the theory of phase noise, oscillator operation specifically and measurement of phase noise.

The authors provide a clear and concise overview of the topic and they support their claims with equations, derivations and specific examples with calculations. The examples are generally applicable to modern problems. The book is comprehensive and covers a wide range of topics related to noise in microwave circuits. This includes the sources of noise, the treatment of noise in linear and nonlinear networks, the noise of common microwave devices and noise measurement. The book is practical and provides engineers with the information they need to understand and measure noise in microwave circuits. The authors include many examples and case studies to illustrate their points.

Overall, *A Guide to Noise in Microwave Circuits* is well-written, informative and comprehensive. The book is especially valuable for practicing microwave engineers and engineers who practice noise measurement. However, it can also serve as a useful introduction to the topic for any mathematically inclined engineer.

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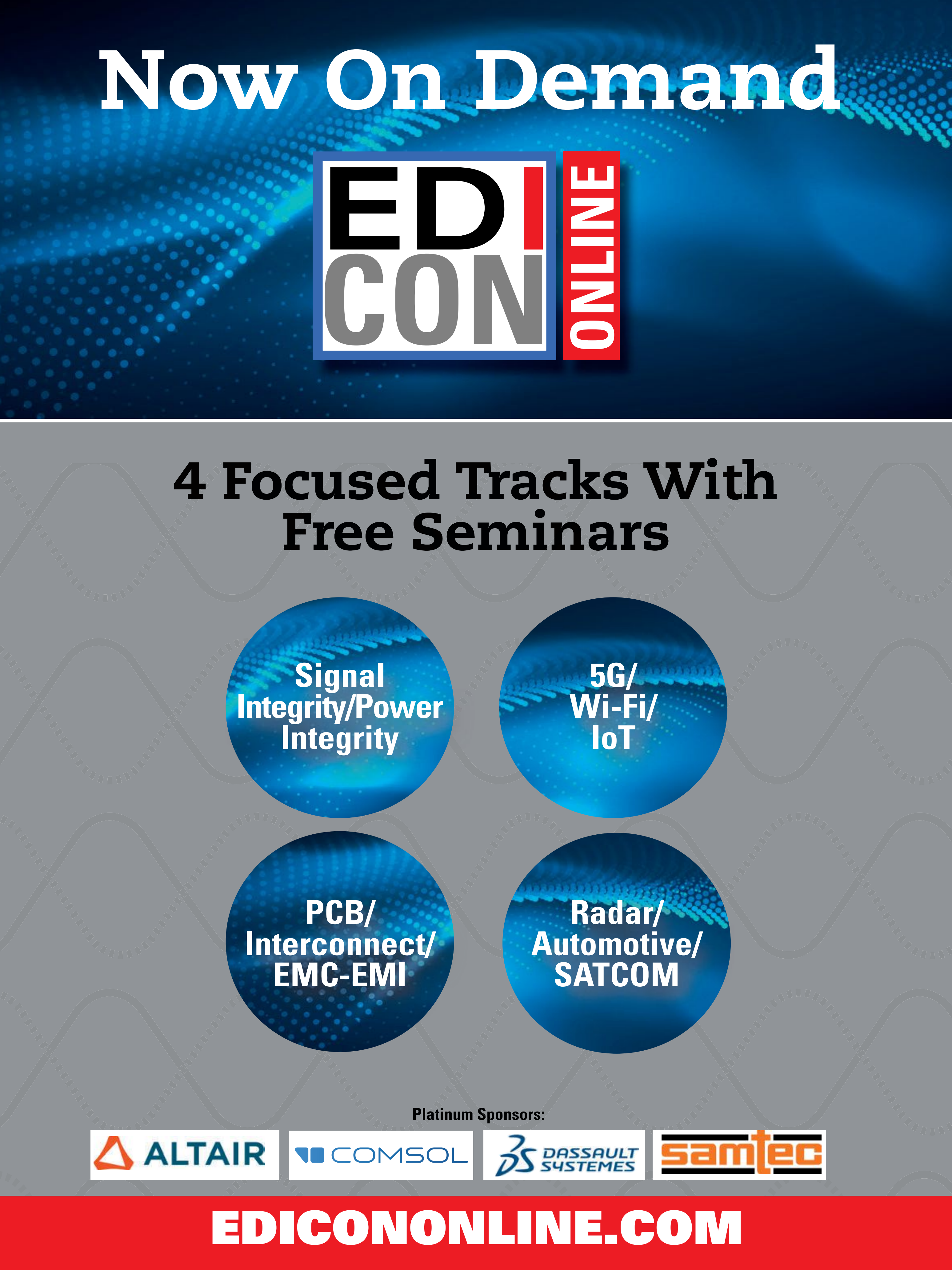
To order this book, contact:
Wiley (December 2021)
wiley.com/en-us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FABS and LABS

Spectrum Control: RF First




When API Technologies rebranded in January 2023 to become Spectrum Control, the name was not new. Spectrum Control is well-known to the industry, having been founded as Spectrum Microwave in 1968. Their first products were sophisticated electronic filters to prevent interference, and over time, Spectrum Control grew organically and used strategic acquisitions to diversify and extend their product offerings and market reach. Spectrum Control continued along this path until they were acquired by API Technologies in 2011.

The rebranding of API Technologies to Spectrum Control is likened to the legend of the Phoenix, rising to signify renewal and rebirth. In this case, the rebirth of Spectrum Control includes well-known brands like Weinschel, Inmet, Aeroflex, Magnum Microwave, Remec Components, Sage Microwave and a number of other acquisitions that extend the company roots back more than 70 years. The renewal of the company means that the goal of developing reliable, high performance technologies for powering and conditioning RF and microwave signals and protecting electronic equipment from electromagnetic interference remains the same. In this rebirth, Spectrum Control takes up the mantle of offering breadth and depth of electromagnetic spectrum capabilities to both the aerospace and defense and commercial industries.

The resurrection of the name embraces the transformation of the company. When CEO Rich Sorrelle joined Spectrum Control two years ago, he began a process to build a new kind of RF company. He implemented steps to:

- Modernize and streamline the go-to-market approach to better align with customers and be more responsive
- Invest in people and culture
- Strengthen the innovation pipeline to expand the solution set and reach new applications
- Improve delivery speed.

The Marlborough, Mass., facility is an example of this process. It has been completely re-imagined with upgrades that create better customer outcomes. These outcomes include better performance from an expanded product portfolio as well as more consistent on-time delivery and greater product reliability. The facility upgrades include:

- Advanced solder workstation
- X-ray analysis
- Increased/higher speed test equipment
- Faster and improved aqueous cleaners and plasma treatment tools
- Higher capacity package-sealing equipment
- Increased electronic monitoring systems for improved speed and accuracy
- Improved higher speed photo documentation equipment for increased reliability
- Class 0 ESD equipment.

This multi-purpose facility includes Spectrum Control's custom solutions team for design and development, as well as manufacturing. Spectrum Control leverages decades of design and manufacturing knowledge and experience to produce RF and mmWave components and subsystems from this facility. The Marlborough team uses that experience, along with a thin film deposition line, complete in-house assembly and hermetic packaging, to develop hybrid microelectronics and integrated microwave assemblies. Further enabling vertical integration capability, this facility has complete in-house electrical and environmental testing capabilities. The commitment to quality is evident by the facility's MIL-PRF-38534 Class K (Space) qualification.

The re-imagining results in disruptive technologies, along with standard and custom products. These products include Spectrum Control's new SCi Blocks that incorporate RF and digital building blocks. These SCi Blocks function as standalone components or they may be integrated into higher-level assemblies. The products designed and manufactured in Marlborough also include SAW filters and oscillators. From this facility, Spectrum Control is the only U.S. manufacturer with high-power SAW filter capability.

With its heritage, investment and "RF first" philosophy, Spectrum Control is being renewed and reborn into a new kind of RF company.

www.spectrumcontrol.com

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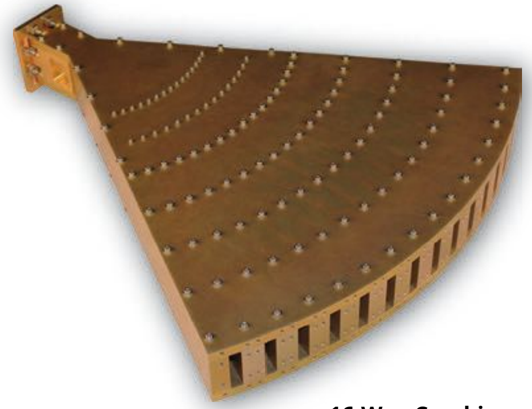

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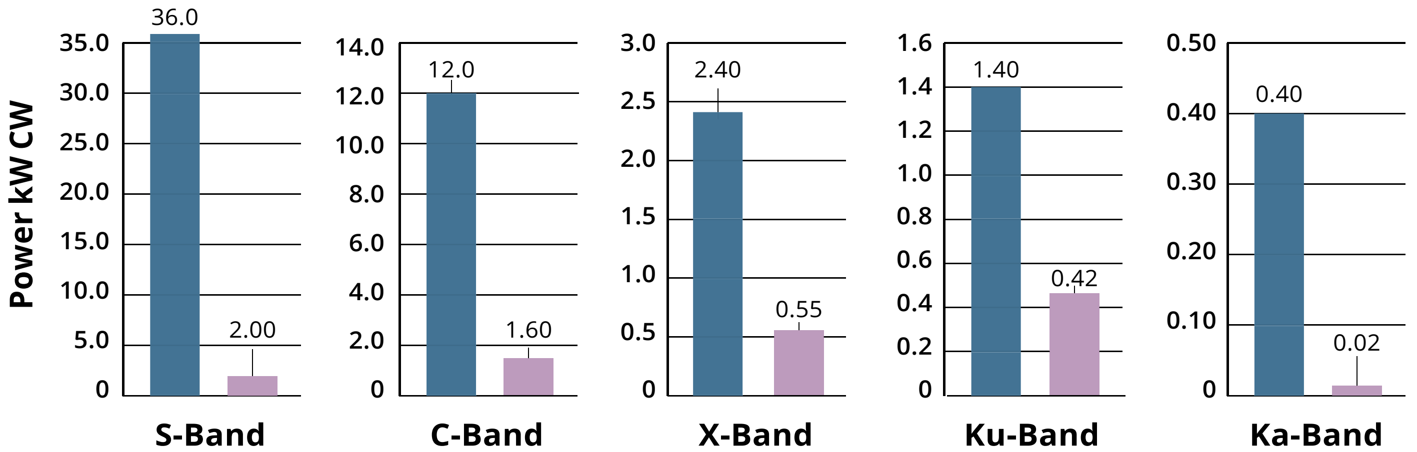
- High Power Density and Low Loss
- Space Efficient, Planar Structure
- Ideal for S, C, X, Ku, Ka Bands

CW Power ■ E-Plane Combiner vs. ■ Radial Combiner



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