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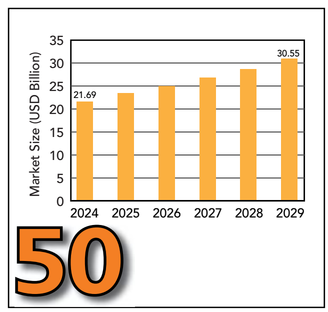

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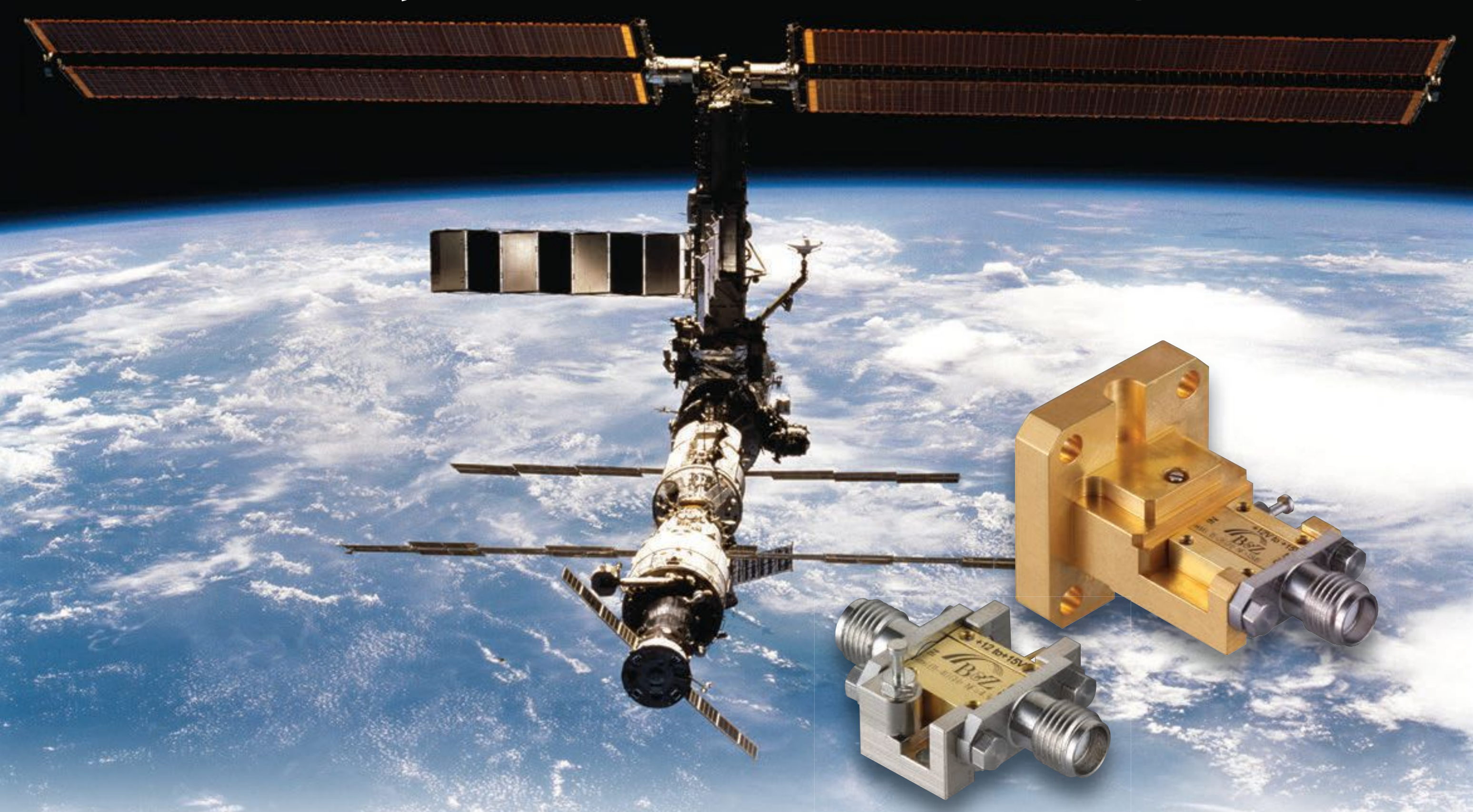

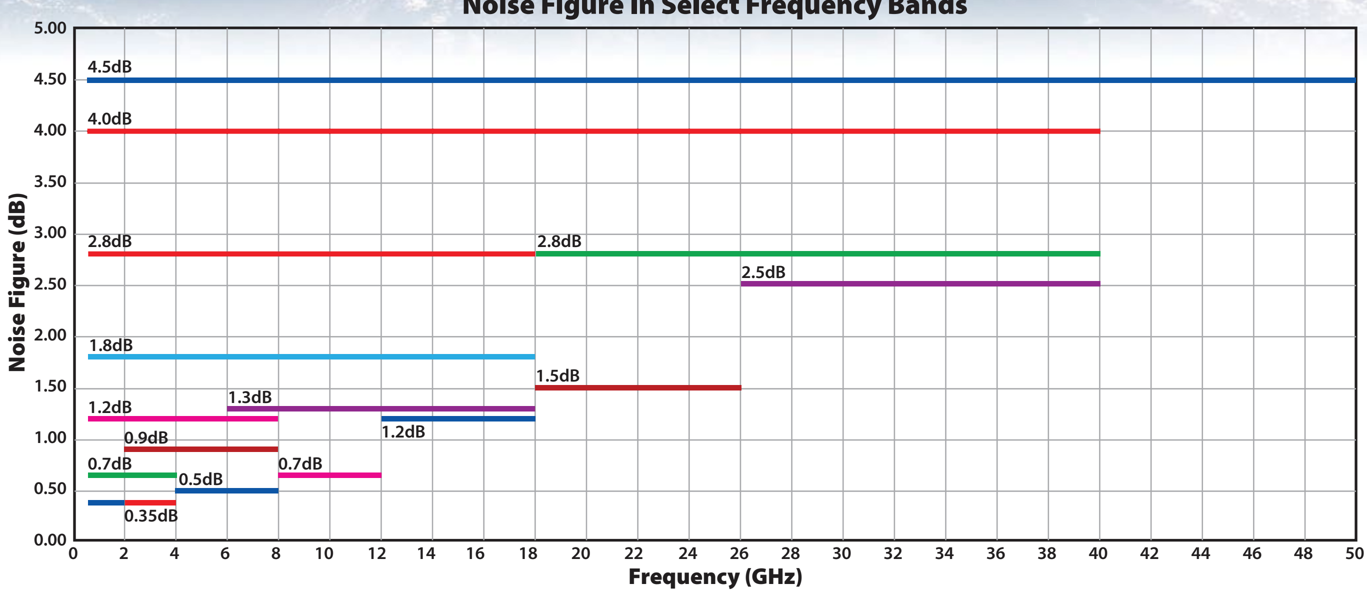

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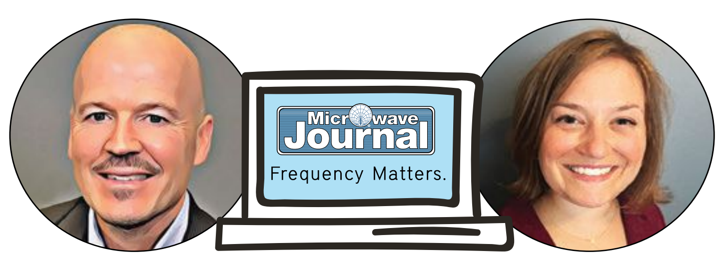

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Cover Feature
Invited Paper

Heterogeneous Integration Brings Compound Semiconductors into the Age of RF CMOS

J. Buckwalter, J. Kim, D. Hodge, M. Tom, N. Vong, M. Soler, B. Coy, A. Dinkelacker, M. J. Kennedy and F. Herrault
PseudolithIC, Santa Barbara, Calif.

Heterogeneous integration promises a new era of high performance, mmWave integrated circuit (IC) technology that leverages diverse semiconductor materials from different foundries to realize a stable and distributed manufacturing ecosystem. While commercial markets have driven large-scale integration of RF silicon or silicon-on-insulator (SOI) CMOS processes, the underlying potential of these technologies to meet future requirements for satellite, wideband or defense systems is constrained to the physics of silicon.

Silicon technologies have become undifferentiated commodity solutions that support high volume manufacturing. PseudolithIC's goal is to drive down the cost of compound semiconductor-based MMICs by an order of magnitude while harnessing CMOS RF, analog and digital circuits to complement the capability of compound semiconductors.

Compound semiconductor devices play a critical role in front-end RFICs, such as beamformers or transmit and receive (TRx) solutions, that support multiple functions using a single, shared set of electronic elements and/or antenna aperture-placing requirements. Achieving the best performance for different circuit blocks demands integration of CMOS with compound semiconductor components for front-end devices such as power amplifiers (PAs) and low noise amplifiers (LNAs). Beamforming arrays (BFAs) are an increasingly large commercial market, allowing for flexibility and efficient use of resources by integrating compact TRx ICs that support wideband operation with high efficiency and sensitivity.

Figure 1 shows a mmWave beamformer with a single antenna aperture that shares the TRx functions for communications and radar sensing. A single aperture with compact PAs and LNAs requires an antenna pitch of one-half the wavelength of the operating frequency, potentially on the order of millimeters at mmWave bands. This becomes a significant challenge above 30 GHz, leading to complicated packaging solutions such as the 3D packaging solution shown in Figure 1. The TRx front-end module in Figure 1 illustrates the 3D integration of a silicon CMOS beamforming RFIC, a compound semiconductor front-end MMIC and an antenna-in-package packaging concept.

MMICs based on compound semiconductors enable performance that exceeds standard CMOS. For example, applications with output power exceeding 20 dBm typically demand GaAs or GaN technologies. ***Table 1*** shows an example of the available suite of device technologies that can be domestically sourced. It categorizes performance by output power, noise figure and switch performance

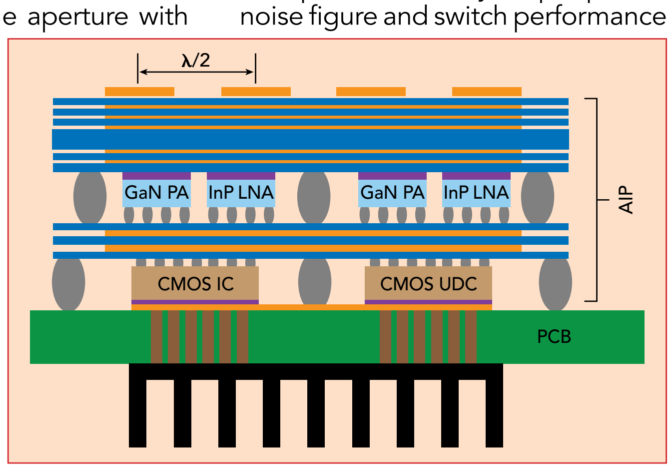


Fig. 1 TRx front-end module.

TABLE 1

DEVICE TECHNOLOGIES FOR HETEROGENEOUS INTEGRATION

Power	Noise	Switch
Gallium Nitride (GaN) Gallium Arsenide (GaAs) Indium Phosphide (InP)	Indium Phosphide (InP) Gallium Arsenide (GaAs) Gallium Nitride (GaN) Silicon-on-Insulator (SOI)	Silicon-on-Insulator (SOI) Gallium Nitride (GaN) Aluminum Gallium Arsenide (AlGaAs) Phase Change Materials (PCM) Microelectromechanical (MEM)

measured as insertion loss.

Realizing a transmit (Tx)/receive (Rx) element with any of these materials increases the cost and complexity and creates a barrier to adoption. This barrier rises as more of these materials are assembled into a multi-chip module or an array of Tx/Rx elements.

PseudolithIC aims to lead commercialization toward rapid research and development cycles for new devices and has identified several vectors that benefit from this approach:

Area: The area of a MMIC is driven by the size of the matching and power supply bypass networks. Most of the area used to support a MMIC is dedicated to passive elements or power combiners, not the transistor. As technology moves into mmWave bands, the area of the MMIC makes using planar packaging solutions for BFA integration unrealistic. Consequently, 3D packaging is the solution, but this approach leads to higher costs. The PseudolithIC approach enables a die with larger dimensions to support a beamforming channel or array of channels.

Uniformity: The regular placement of compound semiconductor transistors across the wafer leads to improved device uniformity. As shown previously, compound semiconductors are typically fabricated on 4 or 6 in. wafers. Most of the chip area is occupied by inductors and transmission lines used in matching and bypass networks, rather than the transistors. Controlling these passive element values is more challenging in a compound semiconductor process than in silicon. Furthermore, the sparsity of the transistors may lead to doping variations across the wafer.

Yield: Due to the manufacturing uniformity, MMIC devices must be screened for known good die. Variations between the performance of different MMICs are significant, and devices are binned through screening. While yields in silicon are well over 99 percent, yields for compound semiconductor wafers are closer to 80 percent.

Cost: MMIC costs are determined by a combination of die area, wafer yield and the screening cost for known good die.

These factors suggest that MMICs will continue to struggle to satisfy the technoeconomic requirements of a high volume market for applications in microwave and mmWave bands, even as several large foundries are developing GaN-on-Si solutions. Despite the success of the GaAs HBT for PAs in handsets, the costs of other MMIC processes have pushed many commercial solutions toward Si or SiGe solutions. Additionally, the tool ecosystem has become incentivized toward processes that can use silicon fabrication processing tools.

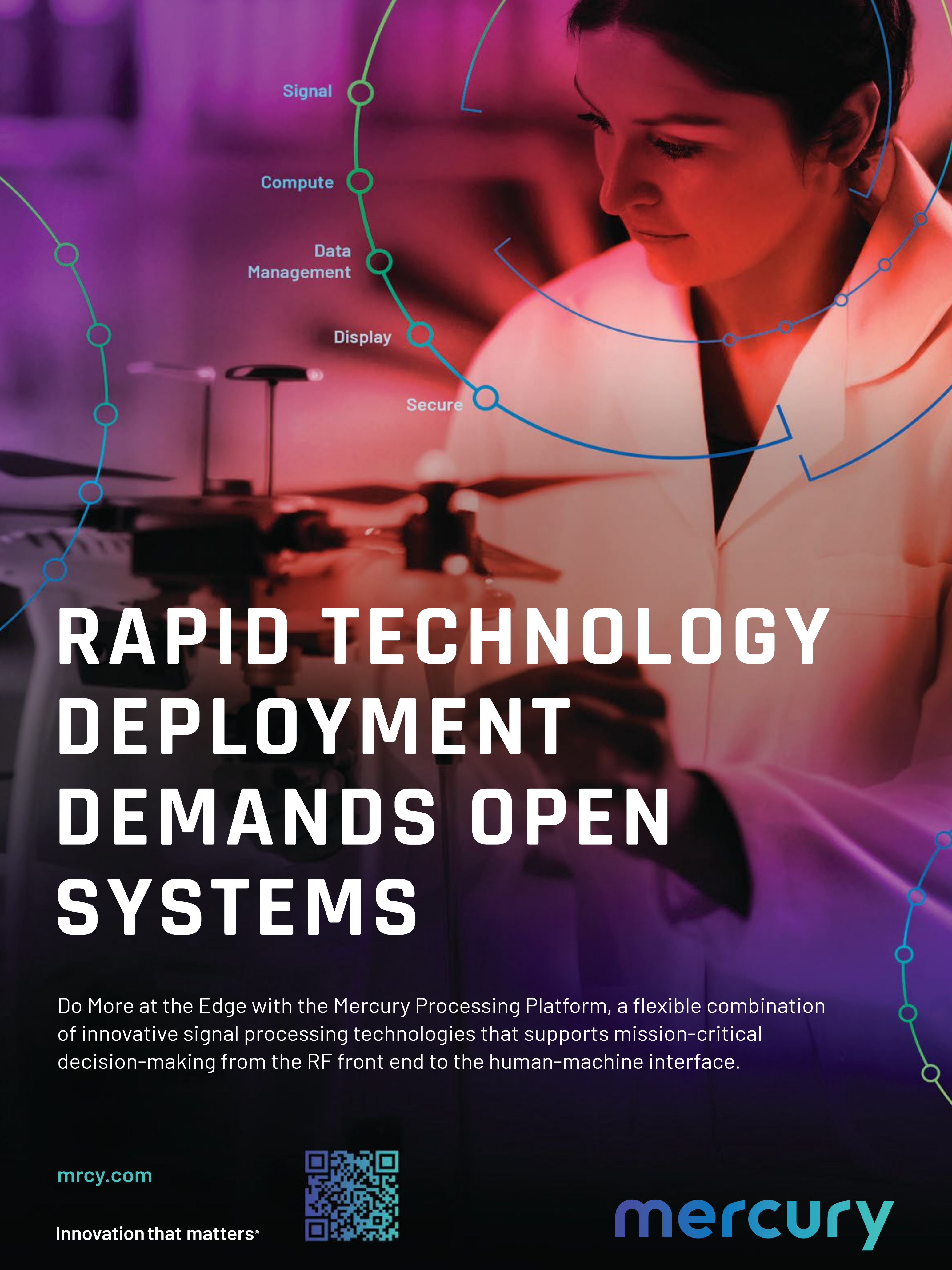
The PseudolithIC approach is a heterogeneous integration process that uses compound semiconductor chiplets integrated into a silicon wafer to address these factors impacting compound semiconductor devices. CMOS plays an important role in the future success of compound semiconductors. It offers critical supporting roles in monitoring and controlling device operating conditions, device optimization for output power and efficiency, RF circuit blocks and analog circuits for linearization. The PseudolithIC platform aims to commercialize an X+CMOS process technology, where "X" is any combination of compound semiconductors. This platform enables any compound semiconductor technology to be combined with CMOS into a single die. It opens a new era in microwave and mmWave systems.

APPROACHES TO HETEROGENEOUS INTEGRATION

Alternative approaches for heterogeneous integration on RFICs have been considered through various advanced packaging and interconnect technologies. These approaches enable the combination of diverse functional blocks, such as high speed digital processors, RF front-ends and passive components, onto a single substrate or within a compact module. Common approaches include system-in-package, where multiple dice are co-packaged and connected; flip-chip bonding, which allows for high-density interconnects and reduced parasitics and through-silicon vias, used in 3D integration to vertically stack components for improved performance and reduced footprint.

Recent research and development efforts have focused on GaN-on-Si processes to support a more affordable platform for GaN device technologies. However, silicon substrates compromise the thermal path from the device to the package heat sink because silicon has worse thermal conductivity than silicon carbide. Moreover, GaN-on-Si processes are incompatible with CMOS device processing, limiting the ability to combine the advantages of analog and digital signal processing to improve device performance.

Advanced interposers, such as silicon or organic substrates, provide a platform for integrating different technologies with precise signal routing and thermal management. The PseudolithIC approach is categorized as an interposer-based approach where silicon CMOS is the preferred interposer. The compound semiconductor wafer is diced into chiplets, which are integrated into a single wafer through cavities etched into a silicon wafer. Interconnects are formed between the chiplet and the silicon interposer. Finally, the backside of the wafer can be metallized to create a thermal backplane that removes heat from the transistor through direct attachment to the silicon carbide or another substrate. PseudolithIC focuses on maintaining the best thermal solution for high efficiency and high-power devices while minimiz-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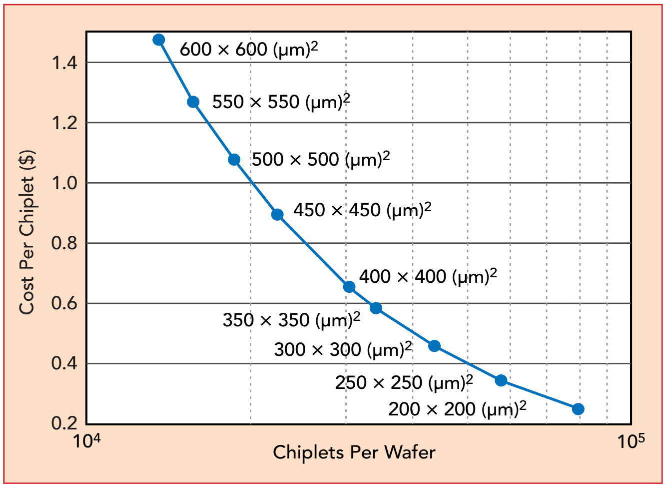

Fig. 2 **Chiplet cost versus size.**

ing the interconnector parasitics between a compound semiconductor chiplet and the interposer. PseudolithIC products support a mix-and-match approach to choosing compound semiconductors. This approach creates competition among suppliers with different device technologies, enabling the OEM to configure the best technoeconomic performance.

PseudolithIC integration combines 8 or 12 in. commercial silicon CMOS wafers with compound semiconductors realized on 4 or 6 in. wafers. In any IC process, the cost of the die depends heavily on the size. ***Figure 2*** shows the cost of a PseudolithIC chiplet versus the chiplet size, assuming 100 percent yield and a wafer cost of $20,000.

PseudolithIC's approach does not demand scaling a compound semiconductor device to a larger wafer diameter. Depending on the transistor size, even a small wafer can provide tens of thousands of transistors. By constraining the wafer area to realize only transistor chiplets, the cost of each transistor drops dramatically relative to a MMIC. The $20,000 4 in. MMIC wafer will produce more than 20,000 450 × 450 μm chiplets, assuming 100 percent yield. The cost of each chiplet will be less than $1.00, driving down the cost of a heterogeneously IC solution. As the size of a chiplet approaches 100 x 100 μm, the chiplet cost drops below $0.20, in this example.

Packaging technology is becoming an important factor in meeting system requirements. This is especially true for the stringent performance, size and power requirements of 5G, radar and wireless communications applications. The packaging approach is also crucial for maintaining a sustainable cost structure.

RAPID PROTOTYPING AND IP BLOCK DEVELOPMENT

The PseudolithIC integration approach enables rapid prototyping with devices at different technology readiness levels. PseudolithIC has demonstrated nascent N-polar Ka-Band GaN MMICs, developed through the support of the Office of Naval Research. Using an 80 nm GaN HEMT process technology, a 6 in. N-polar SiC wafer was dedicated solely to transistor chiplets. In contrast, the silicon interposer could be used to experiment with variations of matching networks to determine, with rough models, the best experimental matching network for the device. This device experimentation model helps to support rapid "lab-to-fab" capability and the insertion of device technologies into beamforming systems.

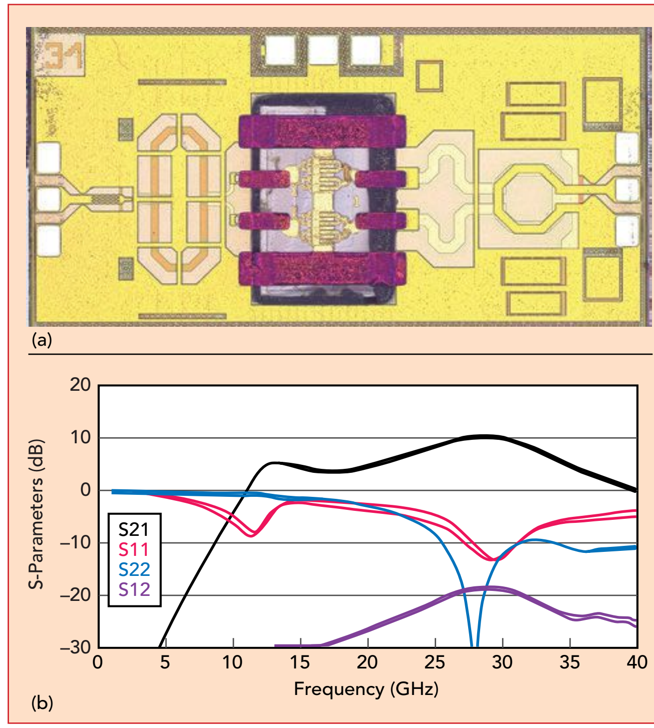

Fig. 3 **(a) 90 nm GaN Ka-Band amplifier. (b) S-parameters of two GaN amplifiers.**

More recently, PseudolithIC has continued to advance the rapid lab-to-fab concept as part of the CHIPS Act. Led by the University of Southern California Information Sciences Institute, the Defense Ready Electronics and Microdevices Superhub, CA DREAMS is one of eight regional innovation hubs established under the Department of Defense Microelectronics Commons Program. This strategic initiative is funded by the CHIPS and Sciences Act of 2022 to develop onshore microelectronics hardware prototyping.

Here, a few highlights from Pseudolithic's rapid prototyping capability are illustrated. The first two examples are based on a 90 nm GaN HEMT technology while the latter two highlight results in using commercial InP HBT and GaN HEMT technologies. PseudolithIC highlights other Ka-Band components that might be integrated into a BFA, including an InP HBT PA that offers excellent gain compression, high efficiency and a high gain 2-stage GaN PA.

Ka-Band 2 W GaN PA

As part of the CA DREAMS Hub, a single-stage Ka-Band PA was designed with the pre-commercial 90 nm GaN HEMT process. The die layout is shown in ***Figure 3a***, and measurements on two devices are shown in ***Figure 3b***. These devices achieve a peak gain of 11 dB at 28 GHz. Preliminary large signal measurements could

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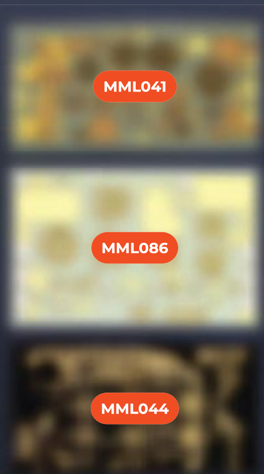
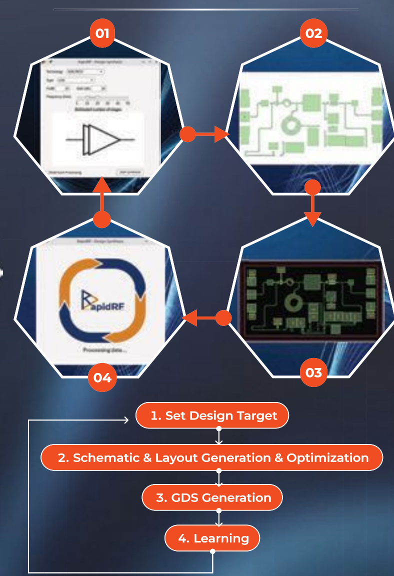
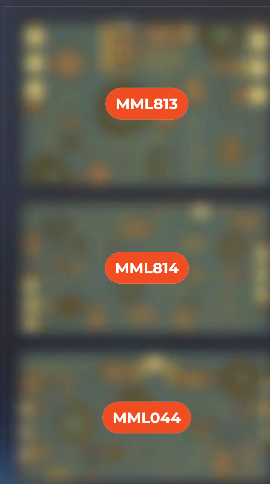


AI MMIC Design Process

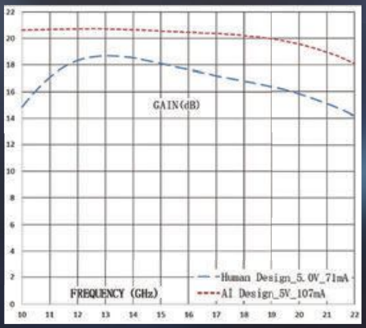


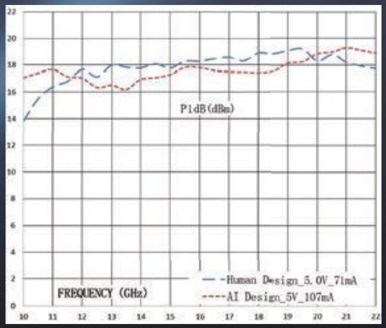
Design Done by RapidRF AI Platform

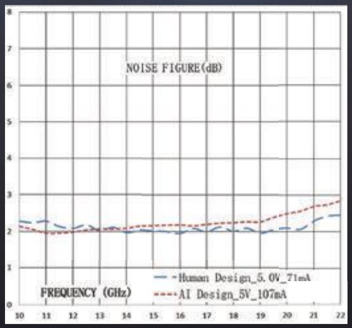
≈5 Hours/Design



Performance Comparisons: RapidRF AI vs Human Engineer Designs







not compress the PA but show linear PA performance to 30 dBm with greater than 25 percent PAE.

Ka-Band 4 W GaN Switch

TRx front-ends require an SPDT switch to control the signal flow from a common antenna node, such as a device antenna, to the TRx paths. A suitable switch technology for the power levels required in commercial and defense beamformers combines high RF power handling, low on-resistance and low off-capacitance. One approach to meet the SPDT requirements is the customization of wide-bandgap devices. ***Figure 4a*** shows the switch realized with the same pre-released 90 nm GaN HEMT technology with a HEMT optimized for a switch chip integrated into a standard silicon interposer wafer using the PseudolithIC process and ***Figure 4b*** shows insertion loss and isolation measurements for multiple devices.

The switch FETs are integrated into a shunt configuration with a quarter-wave line routed back to the common port. Other device technologies, such as SOI switches, offer tremendous capability when coupled with GaN devices to realize unique heterogeneous structures.

Ka-Band 100 mW InP HBT PA

While GaN PAs have received substantial attention for high-power applications, they might not be ideal for pre-driver applications requiring high linearity and efficiency. When working with a single device technology, designers are often limited to pre-driver amplifiers with high DC power consumption to achieve outputs close to 20 dBm. At this output power range, many other device technologies, such as InP HBTs, have become great candidates for the high efficiency pre-driver function. ***Figure 5a*** shows a single-stage 250 nm InP HBT implemented in the PseudolithIC process. ***Figure 5b*** shows the large signal characterization results of three samples measured at 28 GHz. Saturated output power is 20.5 dBm with an output P1dB of 20 dBm and 35 percent peak PAE. This demonstrates the ability of the PseudolithIC platform to use various device technologies in the same silicon platform.

Two-stage Ka-Band GaN PA

Figure 6a shows the micrograph for a two-stage 150 nm GaN HEMT

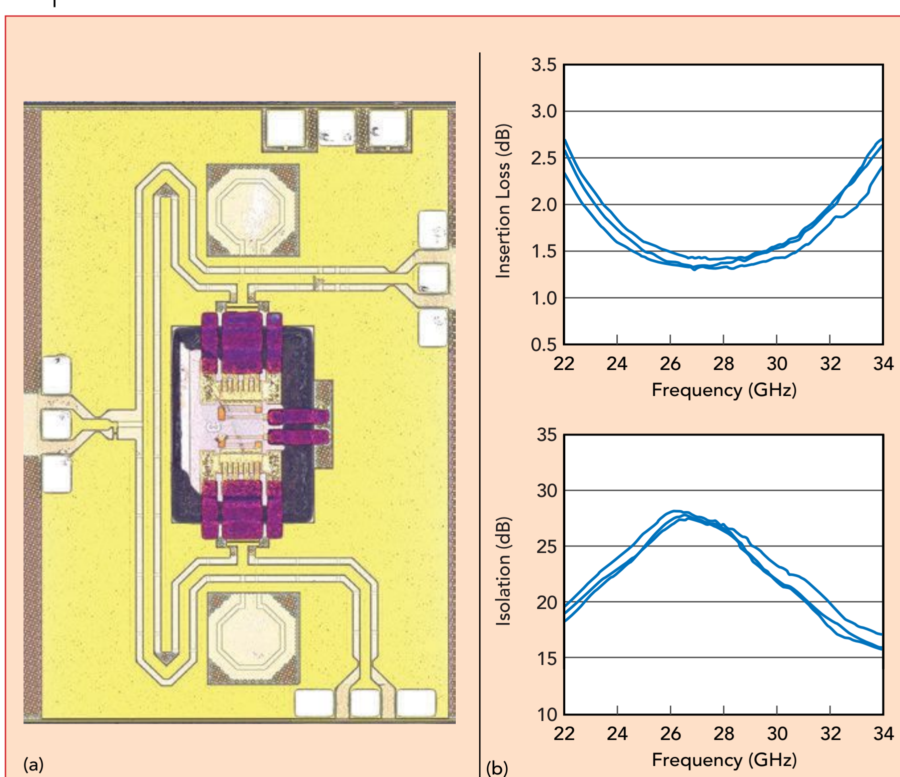


Fig. 4 (a) Single stage 90 nm Ka-Band GaN RF switch. (b) 90 nm, Ka-Band GaN RF switch insertion loss and isolation.


GaN

amplifier. The gain of the PA is more than 21 dB at 28 GHz and the amplifier operates from 26 to 32 GHz. The micrograph of the PA shows several different metal layers that create matching networks that would not have been possible in a typical compound semiconductor process. ***Figure 6b*** shows the small-signal characterization of the amplifier.

CMOS EMPOWERS COMPOUND SEMICONDUCTOR DEVICES

PseudolithIC has demonstrated a variety of semiconductor devices integrated into a silicon interposer. The IP blocks can be used to construct unique front-end IC solutions that support large-scale beamformers or other highly-integrated microwave systems. The advantage of the PseudolithIC approach is that each block can be customized for customer requirements. As shown in Table 1, the device technology that best supports the customer's techno-economic requirements is used to support the development of a Tx/Rx front-end.

PseudolithIC is developing solutions incorporating CMOS digital, analog and RF circuitry to support compound semiconductors in manufacturing, test and operation to address these limitations. The advantages of CMOS are severalfold:

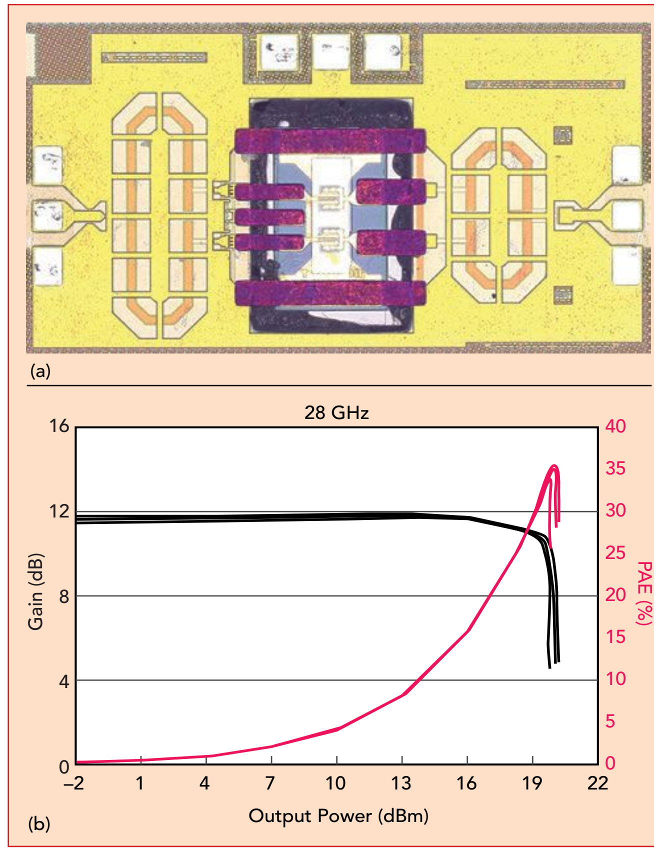


Fig. 5 **(a) Single-stage Ka-Band InP HBT PA. (b) Ka-Band InP HBT PA performance.**

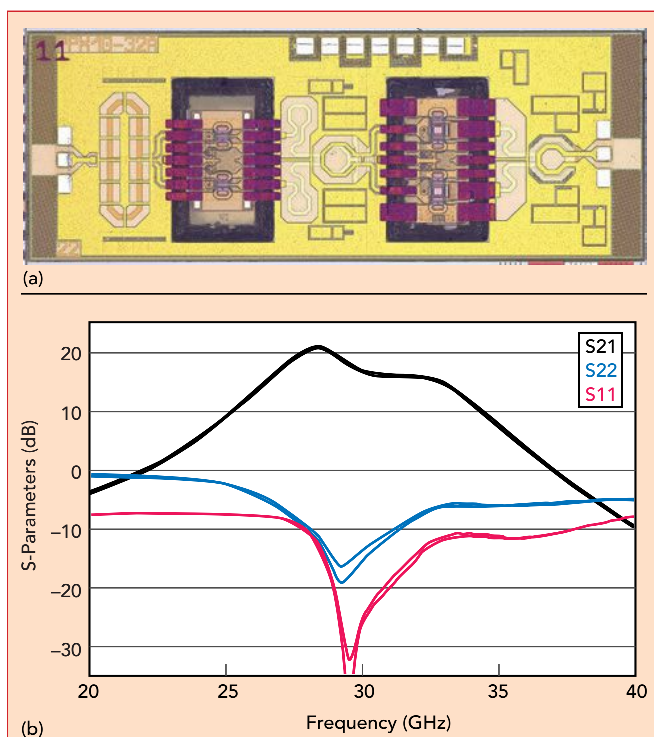


Fig. 6 **(a) Two-stage Ka-Band GaN HEMT PA. (b) Performance of two-stage GaN HEMT PA.**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Built-in self-test: By building self-test with analog signals or digital scan chains, users can rapidly assess the health of a heterogeneously integrated solution without an extended test period.

Analog bias and power management: CMOS process nodes can support biasing circuits that compensate for device variations locally instead of resorting to external monitoring and trim. The threshold voltage of a compound semiconductor device compensates for larger device-to-device variations and circuit yield considerations.

RF signal blocks: Mature CMOS processes can be used for applications up to 90 GHz by developing CMOS blocks such as mixers, phase shifters, attenuators, variable gain amplifiers and frequency multipliers.

Signal processing: An advantage of CMOS is the ability to incorporate digital signal processing. Different functions can be incorporated into the solution by using different CMOS IP blocks, possibly as chiplets.

PseudolithIC's X+CMOS products enable customization of front-end IC solutions for different microwave and mmWave frequency bands. Furthermore, the compatibility of the PseudolithIC solution with standard silicon packaging approaches aids integration into customer solutions.

Figure 7a shows the potential for implementing InP and CMOS technologies in an mmWave receiver via a block diagram and ***Figure 7b*** shows the corresponding micrograph.

E-BAND INTEGRATION OF MULTIPLE TECHNOLOGIES

PseudolithIC has developed a CMOS-enabled W-Band InP HEMT LNA. This design can be integrated

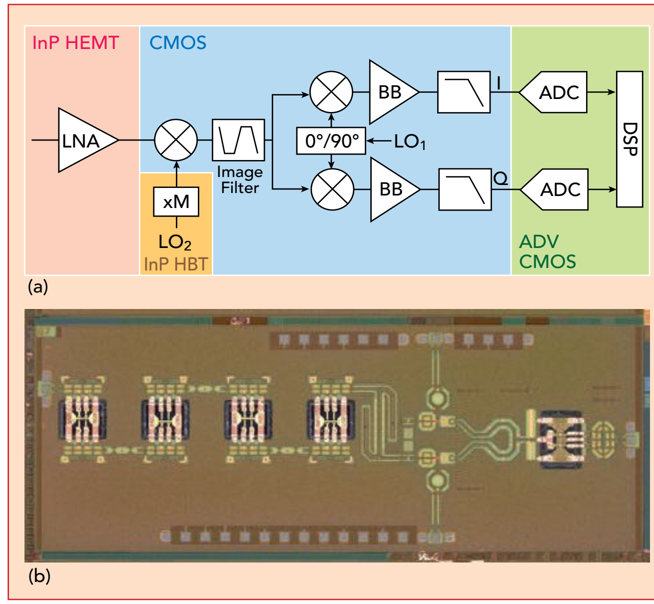

Fig. 7 **(a) Opportunities for heterogeneous integration in an mmWave receiver. (b) Micrograph of mmWave receiver.**

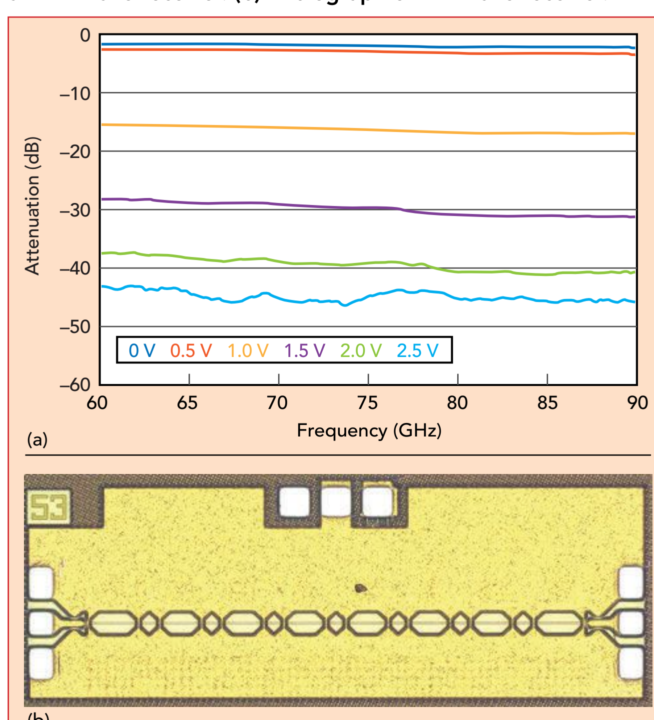

Fig. 8 **W-Band CMOS attenuator covering E-Band (60-90 GHz) with more than 40 dB of attenuation.**

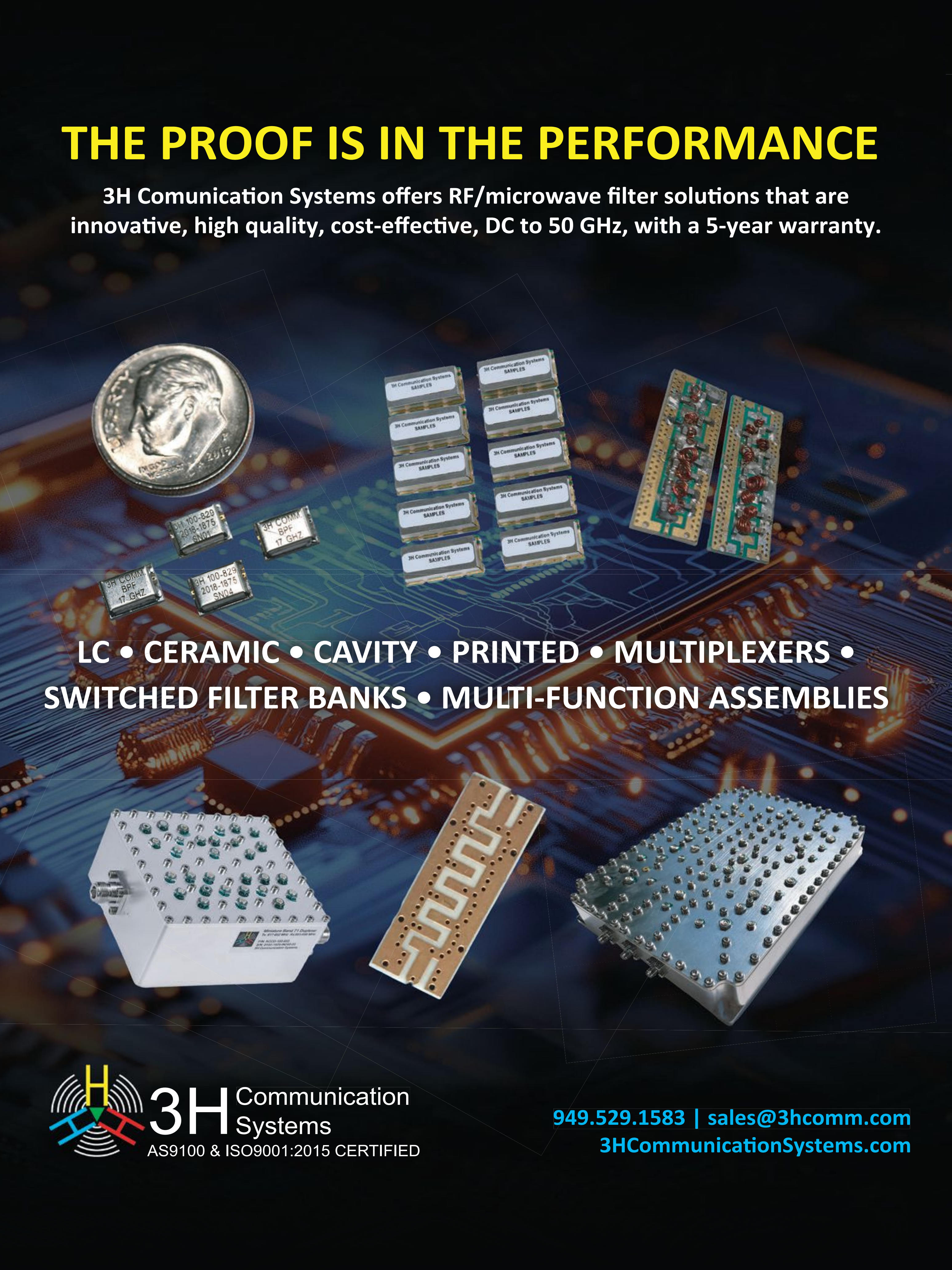
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TABLE 2
PSEUDOLITHIC TX/RX MODULES

Bands		X (8-12)		Ku (12-18)		K (18-27)		Ka (27-40)	E (71-86)
Transmit	Psat (W)	2	5	2	4	2	4	2	1
	Gain (dB)	25	25	25	25	25	25	25	25
	PAE (%)	50	45	40	38	38	35	30	15
Receive	NF (dB)	1.2	1.2	1.5	1.5	2	2	2.5	3
	Gain (dB)	15	15	15	15	18	18	20	25
	DC Power (mW)	10	10	15	15	30	30	20	400*

* with I/Q down-converter and multiplier chain

into higher functionality systems like a heterodyne receiver. A variety of different technologies can be used as building blocks for the receiver. These might include InP HEMT for the LNA, InP HBT for the frequency doubler, RF CMOS for the receiver blocks and an advanced node for the ADC and other signal processing features. Mixing technologies enables the building blocks to optimize the receiver's performance.

To provide gain control for the InP HEMT LNAs, CMOS attenuators have been designed in the PseudolithIC integration process. Gain control ensures the proper signal strength and prevents receiver compression. Using the PseudolithIC integration process results in a more compact solution than standalone GaAs-based attenuators can provide. ***Figure 8*** shows measurements of an 8-stage W-Band attenuator integrated into an X+CMOS solution.

The device has been measured in E-Band, from 60 to 90 GHz, with a control range of 0 to 2.5 V in 0.5 V steps. This design achieves an insertion loss of 1.6 to 2.3 dB with a maximum attenuation value of at least 42 dB over the entire frequency range. The return loss is better than 10 dB under all attenuator states, and the solution has a power compression level of more than 10 dBm. This performance is comparable to GaAs technologies, but at a lower cost. As the industry seeks more sophisticated solutions, the flexibility to add lower cost CMOS IP blocks such as this attenuator becomes a significant advantage of a PseudolithIC solution.

PSEUDOLITHIC PRODUCT ROADMAP

PseudolithIC is developing TRx modules and other highly-integrated RFIC blocks from X- to E-Band frequencies. A summary of the capabilities of these early release parts is illustrated in ***Table 2***. ■

ACKNOWLEDGMENT

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Revolutionizing Spectrum Analysis: The FSWX and Its Exciting Capabilities

Rohde & Schwarz
Munich, Germany

In the rapidly advancing domain of spectrum analysis, traditional methodologies often encounter significant limitations when addressing emerging technologies. These constraints were thoroughly examined in the article "Overcoming the Limitations of Modern Signal & Spectrum Analyzers" in the May 2025 issue of *Microwave Journal*.

At IMS2025 in San Francisco, Rohde & Schwarz introduced the new FSWX signal and spectrum analyzer with its new architecture, meticulously engineered to overcome these challenges with a strong focus on wideband signal analysis. The FSWX's key features and innovations include:

- **Multiple Input Ports:** The FSWX's ability to connect multiple signal sources simultaneously, regardless of whether they operate at the same or different frequencies, enables many new measurement scenarios. With two synchronous input ports, each boasting a 4 GHz analysis bandwidth, users can seamlessly analyze the interactions between diverse signals.
- **Cross-correlation:** Cross-correlation mode is a new built-in feature of the FSWX. A single signal input is internally split into two independent signal paths, each equipped with its own local oscillator and analog-to-digital converter (ADC). This design allows for the application of advanced cross-correlation algorithms in the digital backend, effectively filtering out the inherent noise of the measurement instrument and increasing measurement clarity.
- **Advanced Filter Banks:** The FSWX features comprehensive filter banks that span the entire operating frequency range, diverging from traditional spectrum analyzers that rely on YIG filters. YIG filters are known for having challenging frequency responses and introducing inaccuracies in wideband signal analysis. The filter banks of the FSWX complement YIGs to provide high precision and reliability, optimizing instrument settings for specific applications and reducing the risk of unwanted signal images contaminating results.

PRACTICAL APPLICATIONS

The multiple input ports of the FSWX facilitate phase-coherent measurements of antenna arrays used in beamforming for wireless communications, as well as in airborne and automotive radar sensors. In these scenarios, the phases of individual channels are compared, enabling precise analysis. Unlike traditional vector network analyzers (VNAs), the FSWX supports the analysis of wideband modulated

Fig. 1 Amplifier characterization featuring both frequency and time domain data.

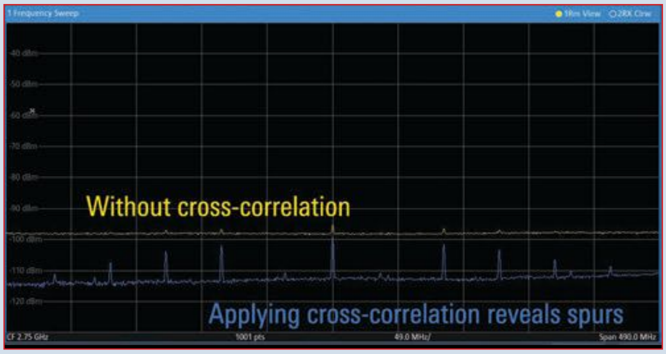

Fig. 2 The built-in cross-correlation gives users a clear view of the signal.

signals that are fully compliant with standards.

Moreover, users can compare a signal against a reference signal, such as the output of a power amplifier against its input. This provides immediate visualization of distortions introduced by the amplifier, including frequency response and nonlinearities. This capability is achieved without requiring prior knowledge of the reference signal. By integrating an additional vector signal generator and an external coupler, the FSWX combines the advantages of traditional signal analyzers with those of a VNA, simplifying the characterization of frequency-converting devices.

As bandwidth requirements continue to escalate and higher-order modulation schemes emerge in mobile communications, measuring error vector magnitude (EVM) has become increasingly challenging. Traditional signal and spectrum analyzers often introduce additional wideband noise, limiting the accuracy of EVM measurements. However, with its cross-correlation feature, the FSWX overcomes this limitation, providing an unobstructed view of the device under test and enabling precise EVM analysis.

ENHANCED MEASUREMENT ACCURACY

Traditional analyzers often require bypassing microwave YIG filters for wideband measurements, which can expose the signal path to interference. In contrast, the FSWX employs broadband ADCs in conjunction with filter banks, allowing for pre-selected signal analysis. This design filters out signal components that may reside on image frequencies, preventing them from contaminating the analysis range — an advantage for measurements conducted through antennas or in multi-radio scenarios.

While traditional spectrum analyzers utilize narrowband paths for spectrum measurements like spur searches, the FSWX offers a wideband signal path with filter banks to speed up measurements by eliminating the cumbersome settling time associated with swept filters. Additionally, it enhances level accuracy by removing the inherent uncertainties of YIG filters. For users who still prefer the narrower bandwidth of a YIG filter, this option remains available as an add-on feature.

INNOVATIVE FIRMWARE APPLICATIONS

In addition to supporting established measurement applications for analyzing communication, radar signals, noise figures and phase noise measurements, the FSWX also introduces user interface features enabled by its dual signal path design.

The CrossAct (cross application control and triggering) firmware feature synchronizes various measurements across different input channels, allowing for simultaneous analysis with multiple tools. This capability simplifies comparisons, such as determining whether the higher harmonics of a radar signal directly impact the EVM performance of a 5G signal.

The IQ-based spectrum analyzer visualizes the spectrum using wideband captured data, directly displaying input signals across different ports and offering comprehensive measurement results. Users can view both frequency and time domain data in parallel, enhancing their analytical capabilities. ***Figure 1*** shows the FSWX characterizing an amplifier, demonstrating simultaneous measurement of input and output signals, spectral regrowth due to nonlinearities and AM to AM conversion near the 1 dB compression point.

The internal dual-path architecture of the FSWX, featuring an internal splitter, enables cross-correlation and offers advanced triggering options. Users can apply an IF or RF power trigger at distinct frequencies, as the two-path design allows for independent frequency settings for each receive path behind the splitter. This flexibility, which includes the ability to reduce inherent noise and reveal spurs not easily seen without cross-correlation, is illustrated in ***Figure 2***. Figure 2 highlights the instrument's dual-path architecture with built-in cross-correlation and the configurable local oscillators that can operate at different frequencies or be switched to phase-coherent mode.

ROBUST OPERATING SYSTEM

In addition to its extensive measurement capabilities, the FSWX platform operates on a Linux-based system, providing a high level of key features for users in high-security environments, such as security and long-term support. This robust operating system ensures reliability and stability, making the FSWX a new choice for demanding applications.

CONCLUSION

The FSWX represents a significant leap forward in signal and spectrum analysis technology, effectively addressing the limitations of traditional methods while introducing features that enhance measurement accuracy, flexibility and efficiency. With its contemporary design — featuring broadband ADCs, multiple input ports, cross-correlation capabilities and advanced filter banks — the FSWX empowers users to tackle complex measurement scenarios that were previously unattainable. As the landscape of wireless communication and radar technology continues to evolve, the FSWX stands ready to meet the challenges of tomorrow, providing excellent performance and insight in spectrum analysis.

VENDORVIEW

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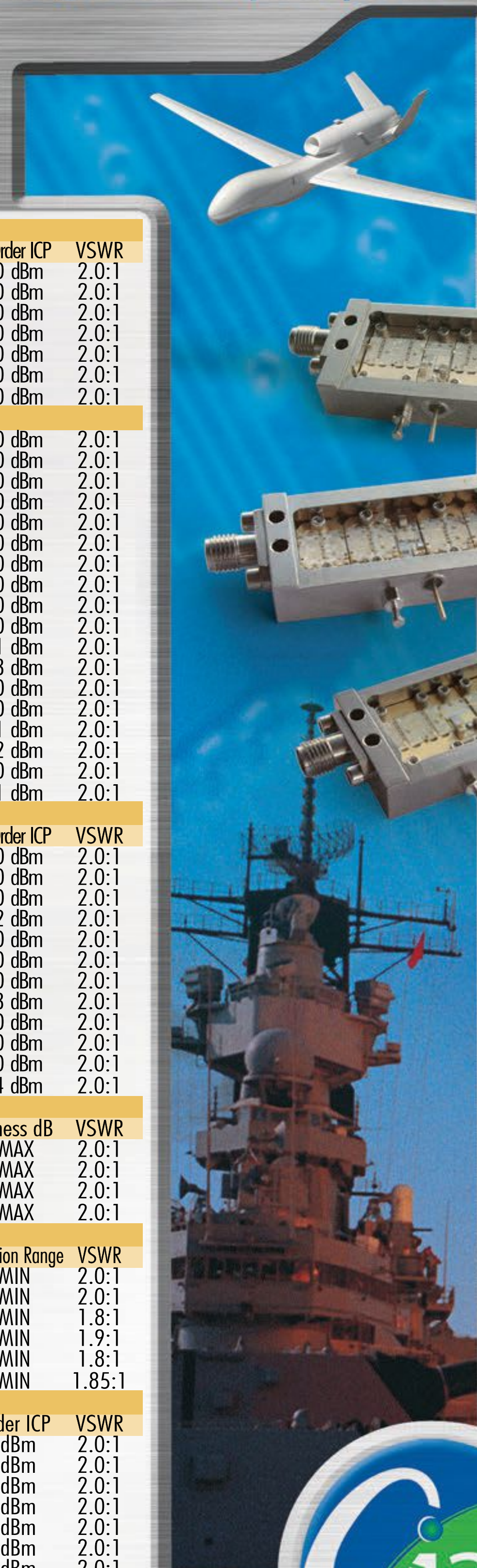

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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NASA Tests Ultralight Antennas to Benefit Future National Airspace

NASA engineers are using one of the world's lightest solid materials to construct an antenna that could be embedded into the skin of an aircraft, creating a more aerodynamic and reliable communication solution for drones and other future air transportation options.

Developed by NASA, this ultra-lightweight aerogel antenna is designed to enable satellite communications where power and space are limited. The aerogel is made up of flexible, high performance plastics known as polymers. The design features high air content (95 percent) and offers a combination of light weight and strength. Researchers can adjust its properties to achieve either the flexibility of plastic wrap or the rigidity of plexiglass.

NASA sandwiched a layer of aerogel between a small circuit board and an array of thin, circular copper cells, then topped the design off with a type of film known for its electrical insulation properties. This innovation is known at NASA and in the aviation community as an active phased array aerogel antenna.

Ultralight Antenna (Source: NASA/ Sara Lowthian-Hanna)

In addition to decreasing drag by conforming to the shape of aircraft, aerogel antennas save weight and space and come with the ability to adjust their individual array elements to reduce signal interference. They are also less visually intrusive compared to other types of antennas, such as spikes and blades. The finished product looks like a honeycomb but lays flat on an aircraft's surface.

Last October, researchers at NASA Glenn and the satellite communications firm Eutelsat America Corp. of Houston, began ground testing a version of the antenna mounted to a platform. The team successfully connected with a Eutelsat satellite in geostationary orbit, which bounced a signal back down to a satellite dish on a building at Glenn. Other demonstrations of the system at Glenn connected with a constellation of communications satellites operated in LEO by the data relay company Kepler. NASA researchers will design, build and test a flexible version of the antenna later this year.

"This is significant because we are able to use the same antenna to connect with two very different satellite systems," said Glenn researcher Bryan Schoenholz. LEO satellites are relatively close, at 1200 miles from the surface, and move quickly around the planet. Geostationary satellites are much farther, more than 22,000 miles from the surface, but orbit at speeds matching the Earth's rotation, so they appear to remain in a fixed position above the equator.

The satellite testing was crucial for analyzing the aerogel antenna concept's potential real-world applications. When modern aircraft communicate with stations on the ground, those signals are often transmitted through satellite relays, which can come with delays and loss of communication. This NASA-developed technology will ensure these satellite links are not disrupted during flight as the aerogel antenna's beam is a concentrated flow of radio waves that can be electronically steered with precision to maintain the connection.

"If an autonomous air taxi or drone flight loses its communications link, we have a very unsafe situation," Schoenholz said. "We can't afford a 'dropped call' up there because that connection is critical to the safety of the flight."

British Soldiers Take Down Drone Swarm with Radio Wave Weapon

At an undisclosed weapons range in Wales, the Radio-frequency Directed Energy Weapon (RF-DEW) tracked and took down a drone swarm during a trial, and it worked with "near-instant effect," the Ministry of Defence (MOD) said.

RF-DEW has been shown in previous trials to be effective from over 1000 yards. But, as the largest such trial in the U.K. to date, this was the first time it took down a whole swarm of drones.

RF-DEW is being developed by a consortium led by French manufacturer Thales, which dubbed the tech "RapidDestroyer" during trials. Thales also collaborated with both the French and British defense ministries on the Marine Mine Countermeasures system that is being rolled out this year.

RF-DEW uses high frequency radio waves to disrupt or damage electronic components inside drones, in what Thales described as a "hard-kill" mechanism. This contrasts with existing systems that jam or confuse drones, Thales said. The technology is considered a low-cost partner to larger-scale, missile-based air defense systems and costs only 13 cents a shot, according to the MOD.

The British Army conducted the trials against 100 small quadcopter drones of two types: The Boresight Raider, a drone with swarming capabilities designed specifically for use in counter-drone tech trials, and the Parrot Anafi, a commercial off-the-shelf camera drone.

Drone swarms, where groups of drones act autonomously or semi-autonomously and in concert with each other, are still in their infancy, with Ukrainian companies trialing swarms designed to resist Russian electronic warfare. The RF-DEW trial is part of a push to increase new technologies in British defense capabilities. There

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are currently no plans to deploy the system in Ukraine, the MOD said.

Rohde & Schwarz Enhances Military Spectrum Monitoring Capabilities

Rohde & Schwarz introduced its transportable monitoring systems for military spectrum monitoring. The company's cutting-edge technology is designed to help armed forces optimize their spectrum management, detect and geolocate emitters and ensure reliable radio communications. The new transportable systems are compact and weatherproof with toolless installation for rapid deployment to any site for controllable direct or autonomous 24/7 operations in multi-purpose or specialized missions. With high sensitivity, wideband monitoring capability and excellent signal processing performance, the systems can cope with any signal environment.

In deployment areas and theaters of operations, spectrum monitoring increases the reliability of deployed forces' radio links, ultimately contributing to mission success and true spectrum dominance.

This helps operators understand and optimize their frequency spectrum in several keyways. It enables them to see how frequencies are being used, identifying unused "white spaces" for more efficient frequency assignments. Operators can detect high loads, find available frequencies and manage capacity more effectively.

EMCON System (Source: Rohde & Schwarz)

Additionally, the solution improves radio coverage by allowing operators to measure actual signal ranges, locate and resolve interference issues, troubleshoot disrupted transmissions and ultimately ensure reliable communications.

Spectrum monitoring systems from Rohde & Schwarz provide critical capabilities for emissions control (EMCON) and search and rescue operations. This includes reliable information about EMCON discipline, detection and location of each emission within a defined area, geolocation of emergency calls and rapid deployment of rescue teams, and increased survivability of soldiers in distress.

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Signal Generator/Controller

ISC-2425-25+

Key Features:

- 30 to +25 dBm (0.1 dB steps)
- Frequency from 2.4 to 2.5 GHz (1 kHz steps)
- Closed loop and feed forward RF power control modes
- User-friendly GUI and full API

300W SSPA

ZHL-2425-250X+

Key Features:

- 300W output power
- Supports CW & pulsed signals
- 42 dB gain
- 60% efficiency
- Built-in monitoring and protection

4-Way Splitter with Phase & Amplitude Control

SPL-2G42G50W4+

Key Features:

- 2.4 to 2.5 GHz
- Drive up to 4 amplifier stages from 1 ISC-2425-25+ controller
- Precise control of amplitude and phase on each path

Coming soon

High Power 4-Way Combiner

COM-2G42G51K0+

Key Features:

- 1.2 kW power handling (sum port)
- 0.1 dB insertion loss
- 0.15 dB amplitude unbalance
- 1° phase unbalance
- 4x N-Type to 7/16 DIN

Mini-Circuits

5G Smart Antenna Market Report

ResearchandMarkets's report on the 5G smart antenna market provides a deep dive into key players, technologies and solutions, evaluating their role in 5G network optimization. It analyzes smart antenna impact on data speed, coverage and service quality, forecasting market trends by type and frequency range. Highlights include the market's growth to $12.8 billion by 2030, energy efficiency gains and their necessity for smart city development. Additionally, it explores smart antennas' future with 6G smart surfaces, enhancing signal transmission and network capacity.

The report evaluates and provides forecasts for the smart antenna market by type (SIMO, MISO, MIMO), frequency range (FR1 and FR2), connectivity and applications. It also assesses 5G smart antenna support of IoT solutions, providing forecasts for applications and services.

It includes revenue forecasts as well as projected smart antenna shipments from 2025 to 2030. It also includes analysis and forecasts for smart surface solutions in 6G communications for 2030 through 2035.

Smart antennas employ MIMO technology, where both transmitting and receiving devices use multiple antennas to exchange data simultaneously. This technique contrasts with traditional single-path systems and is crucial in elevating the performance of 5G networks to support sophisticated applications like autonomous vehicles and high-fidelity communication.

Beamforming stands out as a defining capability of smart antennas. By focusing RF energy into narrow beams directed toward specific users or devices, they enhance signal reliability in environments employing high frequency 5G bands, which are more prone to attenuation. This method optimizes bandwidth and ensures superior signal quality, akin to a focused flashlight beam as opposed to a lantern's diffuse light. The technique's relevance grows with 5G New Radio, notably using mmWave RF susceptible to distance-induced signal weakening.

Prospects point toward the interaction of smart antennas with smart surfaces, now in a research and development phase but anticipated for early application in communication enhancement and sensing solutions. These surfaces will initially integrate into existing infrastructures and later into manufacturing and building materials directly. Their ability to adaptively modify radio signal paths can substantially enhance network capacity, coverage and security, leading the way toward innovative uses in localization and environment-embedded intelligence.

Looking ahead to 6G, challenges with signal propagation will intensify as 6G plans to operate at even higher frequencies than 5G mmWave. The market after 5G will likely focus on ultra-high speed data, ultra-low latency and reliability within short communication ranges.

Next Era of Intelligent Sovereign NTN

According to a new report from ABI Research, the number of newly launched active digital and software-defined satellites (SDSs) in orbit supporting cloud-native networks is projected to exceed 10,000 by 2031, driven by the rise of next-generation low Earth orbit (LEO) satellite networks and network unification efforts.

"As the U.S., Europe and China ramp up investments in LEO satellite networks to compete in the new Space Race, there is an increasing emphasis on software-driven, multi-mission space operations to support both national and commercial objectives," explained Andrew Cavalier, senior space tech analyst at ABI Research. "At the same time, the industry is experiencing rapid consolidation and advancing toward network domain unification — driven by standardization and vertical integration — to improve access to space through more flexible, efficient and accelerated supply chains." Amid this rapidly evolving industry and geopolitical landscape, the winning space strategy now focuses on flexible digital space operations as part of a full-stack space solution that encompasses the entire space value chain, enabling companies and governments to adapt swiftly to global changes.

Cellular standards are increasingly embracing the concept of terrestrial and satellite network unification to create a multi-dimensional system optimized for dynamic resource allocation, spectrum sharing and global interoperability. According to Cavalier, "Emerging technologies like SDS, software-defined ground stations and software-defined wide area networks will play a crucial role in unifying systems by enabling the programmability and reconfigurability of satellite networks."

Satellite networks embracing the cloud are the critical next step for the space industry to unlock the speed, scalability and flexibility that countries demand of modern space architectures. As such, advancing sovereign space capabilities for commercial and defense applications increasingly depends on unifying networking capabilities — driven by satellite and ground station operators adopting cloud-native architectures and integrating with non-terrestrial network (NTN)-compliant terrestrial networks — to break down silos between the telecom and satellite ecosystems.

Many satellite network operators are seizing this opportunity to invest in their networks or collaborate with technology companies. Networks like Amazon's Project Kuiper, SpaceX's Starlink, Globalstar's C-3, Telesat Lightspeed, Iridium, Rocket Lab, Eutelsat OneWeb and

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more are exploring new opportunities with vendors like Thales Alenia Space, Lockheed Martin, Boeing, Airbus Space, MDA Space, among others, to deliver advanced flexible and SDS networks via cloud-native networking principles and enhanced vertical integration.

GSA Forms New 5G RedCap Special Interest Group to Drive Industry Ecosystem

The Global mobile Suppliers Association (GSA) recently announced the establishment of a new Reduced Capability (RedCap) Special Interest Group (SIG) to bring together leading telecommunications companies wishing to track, boost and promote the ecosystem for 5G RedCap network deployments connected IoT devices, FWA devices and service launches.

5G RedCap devices are designed to cater to IoT use cases with requirements for low device complexity and power consumption but moderate requirements for peak data rates. This technology is built upon the 5G New Radio standard and aims to offer a balanced approach to connectivity, enabling implementation and operation of cost- and energy-efficient devices for a wide range of IoT applications.

To deploy RedCap, operators must first have a 5G standalone network, making the ongoing expansion of 5G SA networks worldwide a guide to RedCap readiness. As of February 2025, GSA identified 154 operators in 63 countries investing in 5G standalone. When assessing the global status of 5G RedCap in this latest report, GSA identified 26 operators in 18 countries that are currently investing in RedCap technology, indicating the early stage of its development.

Joe Barrett, president of the GSA, said, "5G RedCap is still in its initial stages of development and growth, particularly when it comes to compatible devices and chipsets. Nevertheless, indications of future growth for 5G RedCap are already emerging. This is why it is time for the industry ecosystem to now work together to promote, track and report on the true status of the technology and collectively expand the RedCap ecosystem globally."

The new GSA RedCap SIG brings together vendors from across the ecosystem to track and promote the status of RedCap products, features and mobile networks. SIG Partners and Members can promote their RedCap-enabled products via the GSA website and GSA Analyzer for Mobile Broadband Databases databases, while the GSA Research Team will support the work of the SIG with regular industry reports and webinars on the global status of technology.

Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Mercury Systems Inc. announced the closure of an agreement that will further advance the company's leadership position in secure processing capabilities for aerospace and defense applications. Mercury has completed the acquisition of **Star Lab**, a subsidiary of Wind River Systems, Inc., that provides anti-tamper and cybersecurity software solutions designed to protect mission-critical processors from advanced attacks. Mercury has worked with Star Lab for more than a decade, leveraging its technology in deployed and awarded Common Processing Architecture and BuiltSECURE™ products, which mitigate reverse engineering and safeguard confidential data from adversarial threats even when a system has been compromised.

COLLABORATIONS

Nokia announced a significant multi-year extension of its strategic partnership with **T-Mobile US**, further expanding and enhancing the carrier's nationwide 5G network coverage and capacity. The agreement will advance T-Mobile's network by deploying next-generation baseband and radio technologies. T-Mobile's network already reaches more than 98 percent of the U.S. population. This collaboration demonstrates its commitment to further extending its high performance 5G capabilities. Under the agreement, Nokia will supply its industry-leading AirScale Radio Access Network (RAN) portfolio — including its latest generation Habrok Massive MIMO and Levante ultra performance baseband solutions. These are powered by its energy-efficient ReefShark system-on-chip technology and will boost T-Mobile's 5G network for maximum performance, efficiency and reliability.

MCV Microwave announced the integration of **ClearComm Technologies** into its operations. This strategic alignment brings together two trusted names in the RF industry to deliver an expanded product portfolio and enhanced manufacturing capabilities. For over two decades, ClearComm Technologies has been recognized for its reliable, high performance filters, duplexers and combiners, serving wireless service providers and critical communications infrastructure. These products are now available through MCV — maintaining the same trusted form, fit and function, supported by MCV's robust engineering and made-in-America production resources.

Partstat announced a strategic partnership with **WIN Semiconductors Corp**. This collaboration aims to provide comprehensive long-term storage solutions for semiconductors, including die and wafer banking, to meet the evolving needs of the electronics manufacturing industry. The partnership between Partstat and WIN Semiconductors combines Partstat's expertise in inventory management and storage with WIN's advanced semiconductor manufacturing capabilities. This alliance ensures that customers receive high-quality semiconductor products with reliable long-term storage solutions, addressing critical challenges in the supply chain. Partstat specializes in delivering innovative supply chain solutions that add value across the entire product lifecycle.

The **GSMA** announced a new partnership with **Samsung Electronics** to improve voice call quality and connectivity over 4G and 5G networks by enabling voice over LTE (VoLTE) by default on devices running Android 15 or later. This initiative supports a seamless global VoLTE rollout, ensuring that all core telephony services such as emergency calling and roaming remain functional as global mobile operators phase out 2G and 3G networks for higher quality 4G and 5G services. Working in alignment with the GSMA's Network Settings Exchange (NSX) and Interoperability Testing services, Samsung is helping to enable consistent and reliable voice services across a wide range of operators and regions by default.

The future of in-flight connectivity (IFC) is multi-band, multi-beam and multi-constellation. **ThinKom Solutions** is at the forefront of making this vision a reality — one that will be enabled by **Quvia**, the first AI-powered quality of experience (QoE) platform for commercial aircraft. Through this partnership, the companies will integrate ThinKom's satcom antenna hardware and Quvia's network management software to optimize QoE in the commercial aviation market. The resulting solution will combine ThinKom's ThinAir® Plus terminal with Quvia Grid, an AI-powered network management solution, to ensure airlines can support multiple concurrent data links with full visibility and control of the IFC experience.

NEW STARTS

Altum RF announced the opening of a new and larger office for its Sydney Design Center. This expansion is driven by growing business demands and includes both increased office capacity and a state-of-the-art RF characterization laboratory. The new office space nearly doubles the size of the previous Sydney office, providing a significant upgrade to support Altum RF's continued growth. This investment underscores the company's commitment to advancing its design and testing capabilities in the region, further solidifying its leadership in the RF industry.

A consortium of major Finnish industrial and academic stakeholders launched a new project that aims to accelerate the development of technologies and RF design related to 5G to 6G networks. The project named **RF ECO3**, which is part of the Business Finland Veturi programme, aims to address challenges related to RF design for ultra-fast communications and the potential for high-resolution sensing in forthcoming 6G radio systems. In particular, these will focus on driving ecological and economic benefits for both industry and society.

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Around the **Circuit**

ACHIEVEMENTS

Narda Safety Test Solutions celebrates its 25th anniversary this year. The success story of the test equipment specialist in electromagnetic field measurement officially began on January 1, 2000. On that day, U.S. company L3 Technologies spun off the German high-tech company from the high frequency test equipment division of the former Wandel & Goltermann Group, pioneers in analog and later digital telecoms measurement technology. Narda STS rapidly began to set global standards as a developer of innovative, high-quality and extremely robust EMF measuring instruments "made in Germany," and continues to play a significant part in shaping the state of the art in this emerging branch of technology.

CONTRACTS

Meridian Space, SpinLaunch's next-generation satellite communication solution, has selected **Kongsberg NanoAvionics** as its exclusive satellite supplier for the initial tranche of its low Earth orbit broadband constellation under a contract valued at 122.5 million EUR. The partnership between SpinLaunch and NanoAvionics includes two prototypes, one of which is an in-orbit demonstrator mission planned for 2026, as well as the development and serial production of 280 satellites. Beyond the initial batch of 280 satellites, the Meridian Space constellation will grow to at least 1200 satellites, as outlined in the company's 2021 spectrum filings.

EnSilica, a chip maker of mixed signal application specific integrated circuits (ASICs), announced that it has been awarded an $18 million design and supply contract by a leading European based supplier of electromechanical products for a Cortex M series Arm-based mixed signal sensor interface ASIC to be used across a range of automotive and industrial applications. The total value of the contract is estimated to exceed $18 million over seven years. EnSilica has been selected due to its significant experience in developing mixed signal design ASICs, alongside a proven track record of bringing automotive and industrial chips to high volume production.

Mtron, a supplier of electronic components and solutions used to control the frequency and timing of signals in electronic circuits, announced a multi-year agreement valued at more than $12 million from a top supplier to the avionics and aerospace industries. The contract includes over 45 different products, including high performance RF filters, crystal resonators, TCXOs, OCXOs and precision clock oscillators. The contract supports the recovering avionics industry and the various Boeing and Airbus aircraft anticipated to be in production past 2030. This contract highlights Mtron's continued leadership in the avionics market, with an average of 16 design wins per commercial aircraft, ranging from collision avoidance radar to communications to engine control.

Around the **Circuit**

Keysight Technologies Inc. has been awarded a contract with **NATO's Naval Forces Sensor and Weapons Accuracy Check Sites (FORACS)** to modernize its testing capabilities for critical radar and electronic support measures (ESM) systems. Under this agreement, Keysight will deliver Radar Target Generator and Electronic Warfare testing solutions to be deployed at NATO Navy bases, enabling the calibration and maintenance of NATO radar systems and the assessment of ESM effectiveness. Modern military and naval forces depend heavily on the accuracy and reliability of their radar and ESM systems for maintaining situational awareness, effective targeting and timely threat detection.

Fortify, along with partners **RTX** and the **Microwave & Millimeter-wave Circuits and Systems Lab** at the **University of Notre Dame**, announced that they have been awarded a contract by the **U.S. Army Command, Control, Communication, Computers, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) Center** to improve command and control (C2) systems utilizing advanced 5G technologies to meet bandwidth, latency and resiliency requirements. This contract allows Fortify to showcase its GRadient-INdex (GRIN) lens antenna design and manufacturing platform for the improvement of C2 systems supporting the warfighter. The focus will be on delivering a cutting-edge prototype GRIN lens antenna system for tactical 5G networks.

Emerson and **ELT Group Deutschland**, the German arm of European defence electronics house ELT Group, have announced a strategic partnership to provide the Finnish Defence Forces with advanced test and evaluation solutions for radar and electronic support measures (ESM) systems. This collaboration underscores ELT Group Deutschland's commitment to working with Emerson as a trusted partner in delivering advanced electromagnetic spectrum operations solutions. Under the contract, ELT Group Deutschland will provide an advanced test and evaluation system for radar and ESM applications, leveraging Emerson's expertise in high performance test and measurement solutions.

REP APPOINTMENTS

ATEK Midas, a designer and supplier of high performance mixed signal silicon ASICs and RFICs and advanced GaAs and GaN MMICs, announced the appointment of **EOX Sales** as their exclusive technical representative serving customers in the southeast, mid-Atlantic and west south-central U.S. regions. Founded in 2000, EOX Sales is a RF/microwave/fiber-optic manufacturer's representative serving the key aerospace, defense, test and measurement, telecoms, industrial, semiconductor and technology research and development customers located from Texas, through the southeast and up to the mid-Atlantic region. They specialize in representing companies supplying RF/microwave components and subsystems, cable and interconnect, optical components and subsystems, embedded solutions and test and measurement solutions.

INVITED PAPER

NFC Market Trends, Drivers and Outlook

Vivek Ravichandran
MarketsandMarkets, Pune, India

Near-field communication (NFC) is a standards-based short-range wireless connectivity technology that operates using electromagnetic fields. It facilitates the exchange of currency and data, enabling the connection of various electronic devices. The speed and convenience of the connection enable data sharing between smartphones, tablets and laptops. The standard is geared towards ease-of-use; NFC users can gesture their phones towards an enabled device and share information without manually establishing a connection.

Figure 1 depicts the global NFC market size from 2024 to 2029. According to MarketsandMarkets, the NFC market was estimated to be $21.69 billion in 2024 and is projected to reach $30.55 billion by 2029 at a compound annual growth rate of 7.1 percent during the forecast period. The prediction of high usage of mobile devices for mobile-to-mobile data transfer and mobile-based payments is expected to create lucrative market opportunities for players in the future.

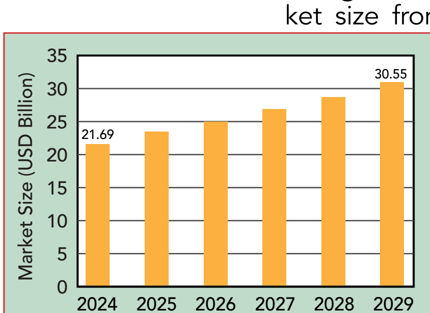

Fig. 1 Global NFC market size by year. *Source:* press releases, investor presentations, interviews with experts and MarketsandMarkets analysis.

NFC MARKET OVERVIEW

The NFC technology market is growing rapidly in all geographical regions. The ease of contactless communication between devices such as smartphones and tablets drives the demand for this technology worldwide. The NFC market has been segmented based on geography into North America, Europe, Asia-Pacific and the rest of the world.

Asia-Pacific hosts some of the world's fastest-growing and leading industrialized economies. The region is witnessing dynamic changes in the adoption of new technologies and advancements across industries. NFC-enabled handsets, wearable devices and products are most used in Japan for payment, customer or product identification and access control applications. Similarly, South Korea, China and India also contribute to the NFC market in Asia-Pacific. The mobile payments market is significantly growing in Asia-Pacific countries.

Contactless debit and credit cards have become popular in many parts of India. Some banks offering NFC-enabled contactless credit cards in India are Citibank, Kotak Mahindra Bank, HDFC Bank, IndusInd Bank, Standard Chartered Bank, American Express (India), ICICI Bank and State Bank of India. As per Reserve Bank of India mandates, all

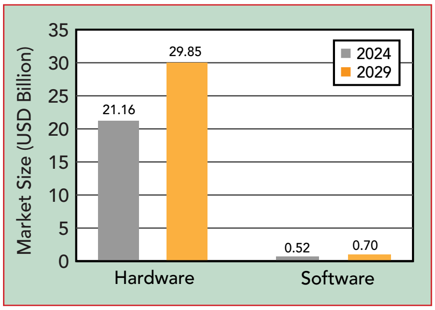

Fig. 2 **Market segmentation. *Source:* press releases, investor presentations, interviews with experts and MarketsandMarkets analysis.**

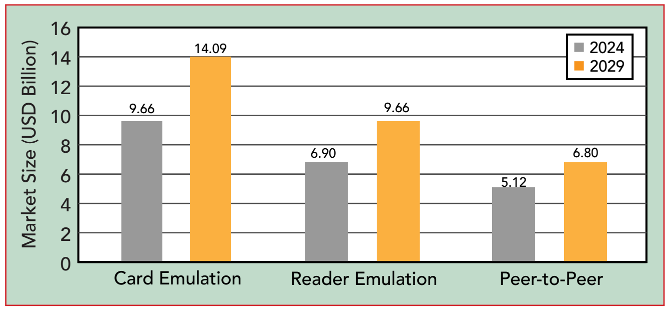

Fig. 3 **Card emulation by operating mode. *Source:* press releases, investor presentations, interviews with experts and MarketsandMarkets analysis.**

payments made using NFC-enabled contactless credit cards in India must be below $23 per transaction. Applications that use NFC payment systems are Apple Pay, Google Pay and Samsung Pay.

PROMINENT NFC MARKETS

Consumer Electronics: The consumer electronics market is the largest end user of NFC and holds a significant market share owing to the commercialization of the technology in smartphones, media tablets, smart TVs, set-top boxes and gaming consoles. The production of NFC-based interfaces has increased, enabling users to control devices using this short-range communication technology. Mobile phones and tablets are the most common devices enabled with NFC technology and are within the reach of all customers. Therefore, the availability of NFC in mobile phones makes this segment promising. Many wearable devices such as smartwatches, fitness trackers, smart glasses and smart rings have NFC technology. This technology allows these devices to interact with other NFC-enabled devices or tags for contactless payments and data transfer applications. For instance, smartwatches from major brands such as Apple and Samsung feature NFC capabilities, allowing these devices to be used for contactless payments, access control and data sharing. The market for wearable devices has lucrative growth potential in the consumer electronics sector, resulting in growth potential for NFC technology in the wearable electronics sector.

Retail: The NFC application has shown tremendous growth in the retail industry, owing to the production of NFC-enabled smartphones. These phones have an embedded NFC chip. With the help of banking gateways and trusted service managers, consumers simply need to wave their phones in front of the NFC tag to deduct the required balance from their accounts. The purchase of goods and services and their payment is made online or at the point of sale. In the retail industry, NFC technology is used for access control, product identification and transaction applications. Product identification and tracking are among the advanced functions of NFC in the retail industry. NFC tags play a crucial role in providing information about products. Using NFC-enabled devices, users can easily identify the location and availability of items. When NFC tags are placed on product shelves, consumers can access personalized information by scanning them with an app that integrates their profile. For example, if a customer has a nut allergy, the app could automatically detect whether a product contains nuts and provide an alert.

Transportation: In the transportation industry, NFC-enabled phone transactions can be used with existing contactless infrastructure without additional investments. NFC enables two-way communications, such as redeeming a ticket and sensing a receipt. NFC forum tags placed behind posters and other printed media (smart posters) allow travelers to touch and read schedules, get special offers and learn about destination highlights. The major applications of NFC in the transportation industry are ticketing and access control. The current trends and customers' interest in mobile commerce have strengthened the ticketing market in the transportation industry. Commuters are looking forward to adopting mobility in all aspects of transit, such as information lookup, journey planning and ticketing. NFC transactions eliminate ticket vendors and queues, thereby reducing frustration among other passengers. The passenger can use NFC to facilitate payment for credit/debit cards, pre-

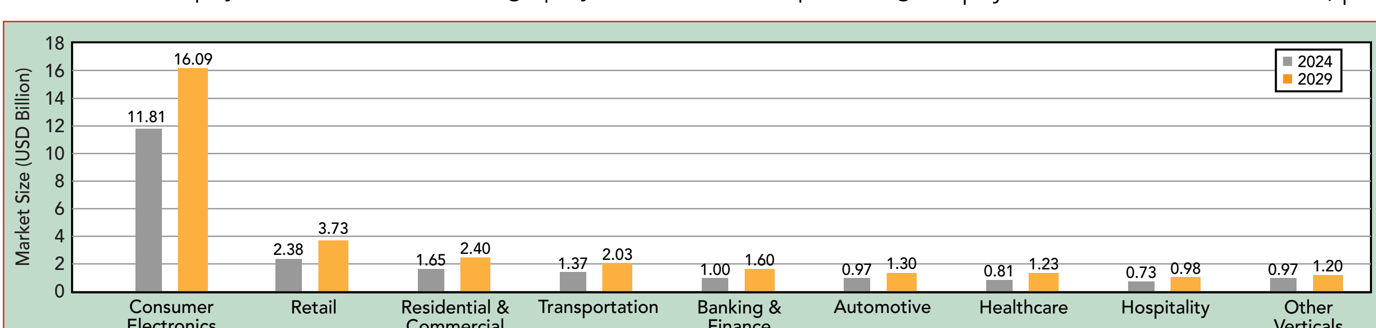

Fig. 4 **NFC market verticals. *Source:* press releases, investor presentations, interviews with experts and MarketsandMarkets analysis. *Note:* Other verticals primarily include education, agriculture and government.**

paid tickets and traveler passes using their smartphone. These tickets are also stored on the phone.

FORECASTS AND SEGMENTATION

NFC hardware is a fixed component integrated into devices such as smartphones and point of sale (POS) terminals to implement the actual NFC transactions. These NFC ntegrated circuits (ICs)/chips are used to handle payments through smartphones, tablets and other electronics requiring a contactless payment system, electronic access control and NFC device pairing to enable data sharing. NFC tags and readers are implemented in various contactless data transfer and transaction use cases, such as mobile payments, access control, data exchange and IoT connectivity. NFC ICs are used for various applications such as mobile phones, secure coupling techniques including Bluetooth and Wi-Fi, tablets, wearables, product differentiation and identification and medical devices. ***Figure 2*** shows the latest MarketsandMarkets segmentation of hardware and software revenue in the NFC market for 2024 and 2029.

The NFC market is segmented by operating mode into card emulation, reader emulation and peer-to-peer applications. In the card emulation mode, an NFC device functions as a contactless smart card. In this mode, the NFC reader creates an RF field. It can be specifically configured to send messages that enable the NFC device to act as a contactless credit card. This mode allows smartphones to replace credit cards, debit cards, transit cards, access cards and more. An NFC device can also include a secure element to safely store information for the emulated card. An external reader cannot differentiate between a smart card and an NFC device in emulation mode, making it especially useful for contactless payment and ticketing applications. ***Figure 3*** shows MarketsandMarkets' estimate for the card emulation, reader emulation and peer-to-peer applications revenue in 2024 and 2029.

The NFC market is witnessing rapid growth owing to the high penetration of NFC technology in consumer electronics devices such as smartphones and tablets. Smartphones and tablets widely use NFC technology for contactless payments and data transfers. Consumers can tap their devices on NFC-enabled POS terminals/ticketing terminals to make transactions. NFC also results in convenient and secure data transfers between devices, such as contact information, files, website links, etc. These NFC-enabled consumer electronic devices can also enable home automation and control. Overall, the NFC technology offers customers convenience, security and flexibility in payment transactions and data transfer applications. ***Figure 4*** shows forecasted revenue associated with NFC use in the most popular market segments for 2024 and 2029.

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2 ~ 4 WKs

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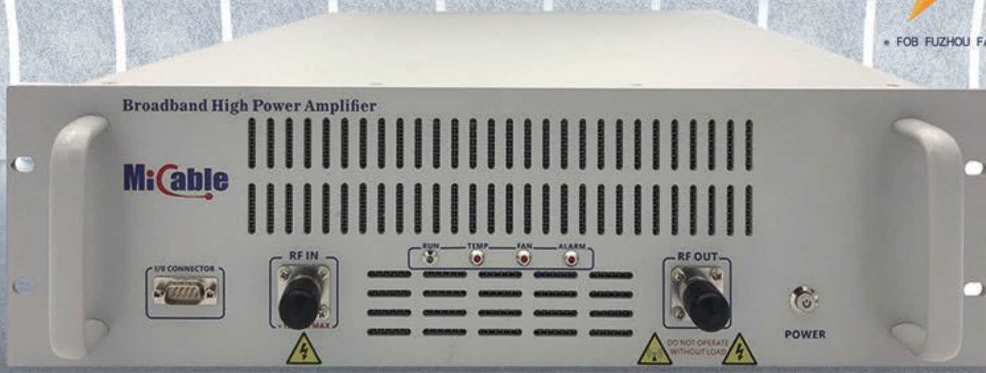
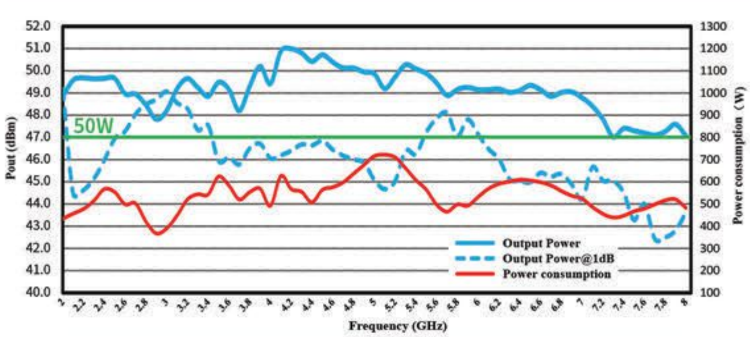
1 ~ 4 pcs

* FOB FUZHOU FACTORY



- **High Power:** Psat 46.5/48.5 dBm, P1dB 41/45 dBm (Min/Typ.)
- **High Gain:** 46.5/48.5 dB (Min/Typ.)
- **Low Harmonic(2nd/3rd):** -15/-25 dBc (Typ.)
- **Low Spurious:** -70 dBc (Typ.)
- **Low VSWR:** 1.5:1 (Typ.)



Pout@ Pin=-3dBm & Pout@1dB &Power consumption (CW, Load VSWR≤1.2, 25℃)

MPAR-020080S47 is a 2~8GHz 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. Other custom amplifiers for special tests and applications are available.

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TABLE 1

MARKET SIZES AND GROWTH RATES OF ADJACENT MARKETS. SOURCE: SECONDARY RESEARCH, INTERVIEWS WITH EXPERTS AND MARKETSANDMARKETS ANALYSIS

Adjacent Market	*Market Size, 2024 ($B)*	*CAGR (%)*	*Forecast Period*
Wireless Connectivity Market	136.1	12.8	2022 to 2027
RFID Market	17.8	11.1	2023 to 2032
Access Control Market	10.4	7.8	2024 to 2029
Authentication and Brand Protection Market	3.1	8.3	2023 to 2028
5G Fixed Wireless Access Market	47.8	39.0	2023 to 2028

FUTURE OUTLOOK

Continued advancements in NFC chip technology, such as improved security and faster data transfer rates, are expected to expand the applications of NFC technology. Integrating NFC with other technologies, like IoT and blockchain, will create new opportunities for secure and efficient data exchange. As the adoption of smartphones and other NFC-enabled devices increases, we can anticipate a wider range of NFC applications, from contactless payments to digital ticketing and access control. ***Table 1*** includes estimated market sizes and compound annual growth rates of adjacent markets. ■

References

1. www.marketsandmarkets.com/Market-Reports/wireless-connectivity-market-192605963.html.
2. www.marketsandmarkets.com/Market-Reports/rfid-market-446.html.
3. www.marketsandmarkets.com/Market-Reports/access-control-market-164562182.html.
4. www.marketsandmarkets.com/Market-Reports/authentication-brand-protection-market-5950532.html
5. www.marketsandmarkets.com/Market-Reports/5g-fixed-wireless-access-market-41266711.html.

INVITED PAPER

Next-Gen RF Connectivity: The Rise of High-Density Multiport Connectors in Military and Avionics

Matthew Radicchi
Times Microwave Systems, Wallingford, Conn.

As military and avionics systems continue to evolve, the demand for higher frequencies and greater density within smaller spaces drives a major shift in RF interconnect technology. Modern aircraft and defense systems require components that are smaller, lighter and more capable of supporting these increasingly high frequencies, all while maintaining performance in extreme environments. At the same time, avionics platforms are being pushed to the limits, with airframes now supporting not just a dozen antennas, but sometimes hundreds of antenna elements. As signal paths multiply and systems push into mmWave frequencies beyond 30 GHz, traditional connectors are no longer sufficient. They present size, weight and installation challenges in modern mission-critical environments operating in the microwave frequency range. This makes the demand for rugged, scalable interconnects urgent to support today's high performance defense technologies.

To meet these growing demands, especially in electronic warfare, radar, surveillance and countermeasure systems, multiport connectors have emerged as a compact, lightweight and high performance alternative. These systems play a role in defense and situational awareness, where real-time data transmission, signal integrity and system reliability are non-negotiable. Multiport connectors offer improved EMI/EMC shielding, reduce installation errors and simplify maintenance, which are important factors as platforms become more modular and operate at higher frequencies.

SWAP DEMANDS OF MODERN RF SYSTEMS

Rising operating frequencies and stringent space requirements drive the ever-evolving RF interconnect requirements across mission-critical systems in avionics and space industries. These systems demand high-density, miniaturized connectors that maintain signal integrity and reliability in extreme environments. Design considerations in this evolution are size, weight and power (SWaP). RF components must meet these requirements by delivering high performance in smaller, lighter and more power-efficient formats, all while maintaining reliability in harsh, mission-critical environments.

The focus on SWaP is driven by the need to optimize today's airframe systems. Smaller and lighter components reduce overall system weight, enabling increased payload capacity, longer mission durations and im-


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proved platform agility. These components must meet complex electrical requirements such as low signal loss and precise impedance matching, along with stringent mechanical requirements for shock, vibration and thermal cycling. Additionally, they must perform reliably in extreme environmental conditions, ranging from high-altitude temperature variations to EMI exposure.

EVOLUTION TOWARD LIGHTWEIGHT SOLUTIONS

The growing emphasis on SWaP optimization has transformed coaxial cable design, as demonstrated by Times Microwave Systems' evolution from MilTech® to MilTech Light-Weight assemblies. This change provided weight savings without compromising signal integrity or environmental resilience and this same progression must occur with connectors. By transitioning from traditional connectors to advanced solutions, system designers can achieve the performance required for high frequency applications while maintaining reliable electrical and mechanical connections in tight spaces. This evolution demonstrates the importance of advancing connector technologies alongside the systems they support, providing the lightweight and small form factors essential to meet the high-density requirements of modern airframes and avionics systems.

LIMITATIONS OF TRADITIONAL RF CONNECTORS

Traditional RF connectors, such as threaded designs, have served reliably for decades across military and aerospace applications. Their durability and mechanical stability continue to make them a strong choice in many scenarios. However, as defense and avionics systems evolve to operate at higher frequencies while simultaneously shrinking in size, these legacy connectors are increasingly pushed beyond their original design limits.

Operating at high frequencies introduces several signal integrity challenges. Shorter wavelengths place greater demands on connector design to maintain signal integrity, demanding tight dimensional tolerances to minimize reflections and losses. Impedance mismatches become more detrimental as frequencies rise, where even minor imperfections represent a larger proportion of the signal's wavelength. Signal attenuation, or insertion loss, also increases at higher frequencies due to the skin effect, which causes current to concentrate near the surface of the conductor. This results in higher resistance and greater energy loss along the transmission path.

Beyond electrical limitations, traditional connectors pose mechanical and integration challenges in high-density environments. Threaded coupling mechanisms, though secure, require manual engagement for each connection. In systems with dozens or even hundreds of interconnects, this can lead to longer installation times, increased maintenance complexity and a higher risk of misconnection. Additionally, the physical footprint and cumulative weight of multiple threaded connectors can become a barrier to meeting modern SWaP requirements.

As next-generation military and avionics platforms continue to increase in complexity by supporting more antennas, sensors and data paths at target frequency ranges approaching 40 GHz, the limitations of traditional RF connectors become apparent. In these environments, advanced connector technologies deliver improved electrical performance, reduced size and weight and simplified installation, making them better suited to the high frequency, high-density demands of modern systems. With applications ranging from fighter jets to unmanned aerial vehicles, these connectors enable smaller, lighter and more resilient avionics systems.

MULTIPORT CONNECTORS: KEY TO MODERN AVIONICS

A single multiport connector consolidates multiple connections into one unit, as exemplified in ***Figure 1***. Multiport connectors contribute to a compact system design. Having fewer individual connectors contributes to weight savings and reduces installation complexity. Users can mate multiple cable assemblies at once instead of threading individual connectors on each cable while still maintaining key performance characteristics like vibration handling.

Other key considerations for connectors in these environments include:

- Weight: Advances in fuel efficiency rely on weight reduction and the evolution of frequency requirements is pushing the development of increasingly lightweight, small and high-precision RF technologies.
- Density: The increase of antenna arrays in military avionics necessitates a corresponding increase in electronic box deployments and interconnections, concurrent with the rise in operating frequencies and resultant reduction in wavelength to demand advanced, high-density interconnect technologies.
- Shock and vibration: Microphonic noise, arising from vibrational movement in airborne antenna connectors, can impact RF signal integrity. Achieving robust performance requires minimizing cable-connector clearances to enhance vibration resilience, with spring-loaded interfaces providing a solution to reduce noise and prevent contact plating degradation, thereby improving electrical and mechanical characteristics.
- Temperature: Temperature requirements stem from high altitudes, speeds and frequencies and make material considerations more complex.
- Maintenance and access: Aircraft exterior antennas are susceptible to damage and demand quick repairs. Unfortunately, their accessibility within avionics systems is often poor, leading to complex and lengthy maintenance.

Fig. 1 **Examples of multiport connectors.**

Fig. 2 Example of an F-35.

OVERCOMING CHALLENGES WITH MULTIPORT SOLUTIONS

To address these mounting challenges, Times Microwave Systems developed a family of multiport connector systems, replacing threaded connectors with a spring-loaded push-on connection. Multiport connectors like Times Microwave's M8® and Mini Multiport offer a compact alternative to threaded connectors, enabling higher cable density and reducing size and weight to meet SWaP goals. Keyed configurations improve installation accuracy and minimize the risk of misconnection. Designed for high-vibration environments, they deliver performance with EMI/EMC shielding. Unlike traditional connectors, they also support coax, fiber and octo-contact options, making them a versatile solution for modern systems, such as the F-35 shown in ***Figure 2***.

Times' product family evolution reflects ongoing innovation in modular RF technology, with newer variants engineered to address specific application challenges while ensuring mission-critical performance in demanding environments.

THE FUTURE OF RF INTERCONNECTS

Today, tens of thousands of multiport solutions serve on mission-critical platforms, with hundreds of thousands of flight hours logged in demanding environments — from supersonic fighters to naval aircraft. These compact, rugged connectors have redefined RF interconnects by enhancing EMI shielding, simplifying installation and maximizing space efficiency.

As military and aerospace systems push for smaller, lighter and higher performing components, traditional connectors can no longer meet modern SWaP, frequency and reliability demands. Multiport connector solutions — like the M8 — have emerged as enablers of next-generation performance, offering a compact, rugged and scalable approach to RF connectivity. By simplifying installation, improving signal integrity and withstanding harsh environmental conditions, these connectors help defense and aerospace platforms maintain peak operational readiness and performance.

With over three decades of innovation, Times Microwave Systems continues to provide high frequency RF connectivity, delivering reliable, future-ready solutions that keep defense and aerospace platforms operating at peak performance. ■

Small-Signal Modeling for Multi-Finger GaAs pHEMTs

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Henan University of Science and Technology, Luoyang, China

In this article, the autoencoder (AE) concept is applied to the Extreme Learning Machine (ELM) algorithm to develop a modeling method for multi-finger gallium arsenide (GaAs) pseudomorphic high electron mobility transistor (pHEMT) layouts. To avoid local optimum solutions, the Sparrow Search Algorithm (SSA) optimizes the weights and thresholds generated by the Deep ELM (DELM) algorithm, creating the SSA-DELM algorithm. To validate the accuracy and effectiveness of the SSA-DELM algorithm in small-signal modeling, its performance is compared with the Back Propagation (BP) and Support Vector Regression (SVR) algorithms. The proposed SSA-DELM algorithm achieves greater than 99.7 percent accuracy in the small-signal modeling of GaAs pHEMTs up to 50 GHz for various total gate widths.

Pseudomorphic GaAs HEMTs outperform GaAs HEMTs in current conduction and cut-off frequency.[1] Due to their high electron mobility, high gain and low noise performance, GaAs pHEMTs have become crucial components in low noise amplifiers, voltage-controlled oscillators and other nonlinear RF circuit applications.[2] Developing relevant pHEMT models to meet application-specific requirements is essential during the design of high frequency circuits. Meeting these needs requires effective and general modeling techniques.

The study of device modeling techniques has become fundamental in microwave circuit design. Accurate small-signal equivalent circuit models are essential for developing reliable large-signal and noise models.[3] Artificial neural networks (ANNs) are a key method for characterizing and modeling microwave devices. They enable device behavior to be modeled without understanding the internal mechanisms, thus reducing computation time and speeding up design optimization.[4,5] Various neural network techniques have been widely used in recent publications. However, ANN techniques require tedious parameter descriptions, while SVR can suffer from underfitting and overfitting due to data set and hyperparameter choices. Moreover, existing models often lack good generalization performance for modeling the relationship between GaAs pHEMT RF characteristics and gate width.

To address these issues, the work described in this article adopts the SSA to optimize the DELM for modeling GaAs pHEMTs under small-signal conditions. The SSA converges to the global optimal solution faster than genetic and particle swarm optimization algorithms. Thus, the SSA optimizes the DELM's weights and thresholds, ensuring the fitness function remains minimal in a multi-finger layout.

GAAS PHEMT SMALL-SIGNAL EQUIVALENT CIRCUIT MODEL

The small-signal equivalent circuit model of a GaAs pHEMT is shown in ***Figure 1***. The parasitic part of the circuit comprises nine bias-independent elements (C_{pg}, C_{pgd}, C_{pd}, L_g, L_d, L_s, R_g, R_d and R_s), where the intrinsic elements are within the dashed box.

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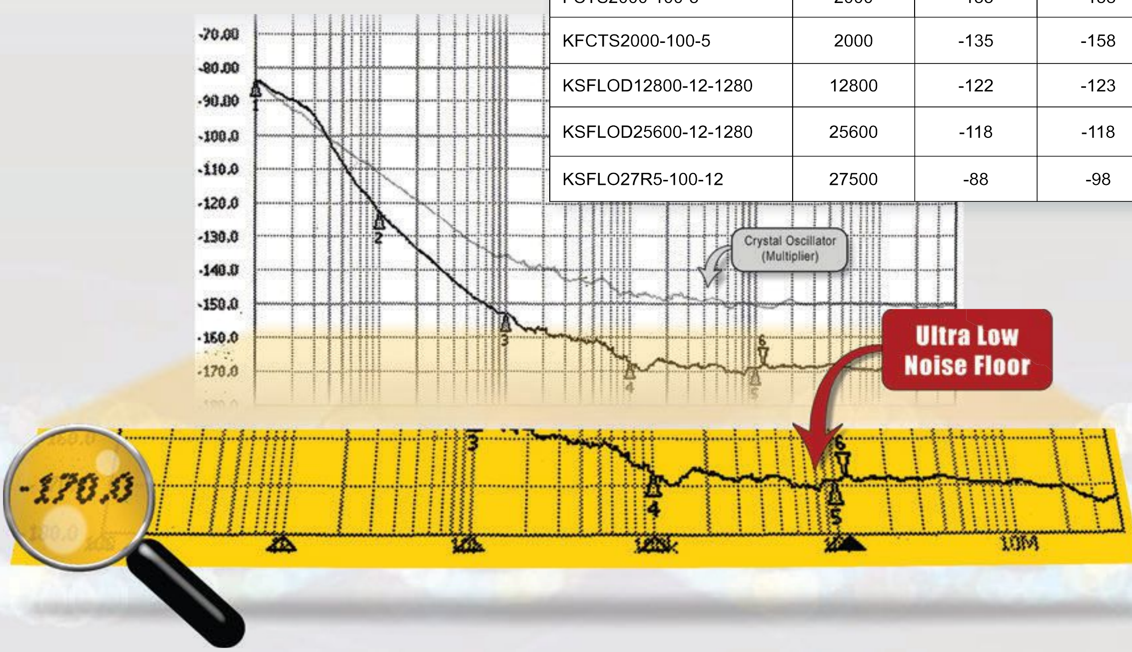
VFCTS125-10	125	-156	-165	
VFCTS128-10	128	-155	-160	
FCTS800-10-5	800	-144	-158	
FCTS1000-10-5	1000	-141	-158	
FCTS1000-100-5	1000	-141	-158	
FSA1000-100	1000	-145	-160	
FXLNS-1000	1000	-149	-154	
KFCTS1000-10-5	1000	-141	-158	
KFCTS1000-100-5	1000	-141	-158	
KFSA1000-100	1000	-145	-160	
KFXLNS-1000	1000	-149	-154	
FCTS2000-10-5	2000	-135	-158	
FCTS2000-100-5	2000	-135	-158	
KFCTS2000-100-5	2000	-135	-158	
KSFLOD12800-12-1280	12800	-122	-123	
KSFLOD25600-12-1280	25600	-118	-118	
KSFLO27R5-100-12	27500	-88	-98	



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R_{ds} is the drain-source interchannel resistance and R_i is the input gate-source resistance. C_{gs}, C_{gd} and C_{ds} are the gate-source, gate-drain and drain-source capacitance, respectively.

SPARROW SEARCH OPTIMIZED DELM ALGORITHM

DELM Algorithm

The ELM is a single hidden layer feedforward neural network[6] that does not require fine-tuning parameters. This results in faster learning and more effective fitting. However, adjusting parameters for optimal results can make the process complex when modeling devices with different characteristics.

AE is an unsupervised neural network model that extracts valuable information from input data while reconstructing it, learning beneficial data characteristics. Combining AE with ELM creates a DELM, allowing multilayer network structures to capture more intricate data characteristics. An ELM with only a single hidden layer cannot capture the data's effective characteristics when confronted with input and output variables with differing grid widths. Creating the DELM solves this problem.

With its superior nonlinear fitting capability, deep learning is widely used for modeling complex systems like microwave modules. DELM comprises multiple ELM-AEs, with input data X and output data Y. The ELM-AE equalizes the input and output of the ELM by setting Y = X. This transforms the hidden layer feature, H, into an encoding of the input training sample, generating its output weight matrix, β. The output features of each layer are mapped from the hidden layer features and samples by determining β from ***Equation 1***:

$$\beta = \begin{cases} \left(\frac{I}{C} + H^T H\right)^{-1} H^T \quad X, N \geq m \\ H^T\left(\frac{I}{C} + HH^T\right)^{-1} X, N < m \end{cases} \tag{1}$$

Where:

C is a user-specific parameter to pursue good generalization performance

N is the number of training samples

m is the number of hidden layer neurons

I is the unit matrix

The output weights expressed in equal dimensions can be described by ***Equation 2***:

$$\beta = H^{-1}X, \beta^T\beta = 1 \tag{2}$$

Multiple ELM-AEs are stacked to create a multilayer network feature extraction model. The output feature of each layer maps the implied layer features to samples using the output weight matrix and vice versa. The output feature of each layer is expressed in ***Equation 3:***

$$H_1 = h(W_i H_{i-1}) \tag{3}$$

Figure 2 shows a DELM with *h* hidden layers. During training, input data is used as the first ELM-AE's output to determine the output weight β^1. Then, the output matrix H_1 of the first hidden layer is used as the input data of the second ELM-AE. After layer-by-layer unsupervised training, ELM-based supervised training is used for the final layer to solve output weights.

SSA

The SSA is inspired by the behavior of sparrows during their foraging process, particularly their social activities when searching for food and avoiding predators. This algorithm is especially suitable for solving complex optimization problems. The search algorithm's core idea is to simulate a sparrow population's dynamic interactions to discover optimal solutions within a specific search space.

In the SSA, individual sparrows are divided into three roles: discoverers, followers and sentinels. Discoverers play a pioneering role in the group, actively seeking food sources in the environment. They are not just foragers; they also communicate the food information they find to other individuals, guiding the group's foraging behavior and ensuring the success and survival of the entire group.

Followers are those individuals who learn from the discoverers and closely follow their actions. Their main task is observing the discoverers' behavior and competing for food resources to maximize their benefits. This emphasis on cooperative behavior not only helps improve foraging efficiency but also strengthens the transmission of information and resource sharing

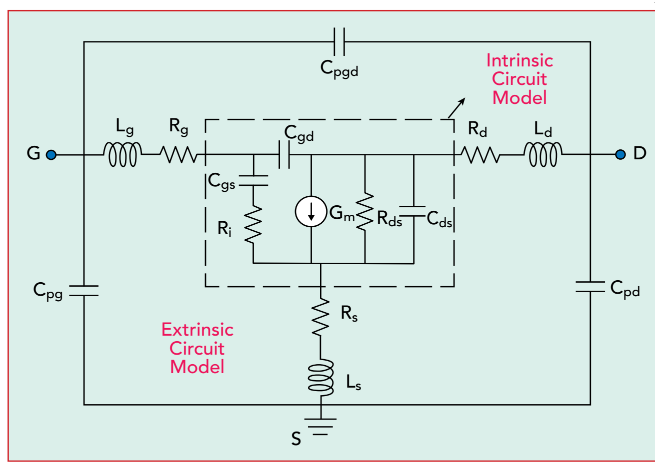


Fig. 1 GaAs pHEMT small-signal model.

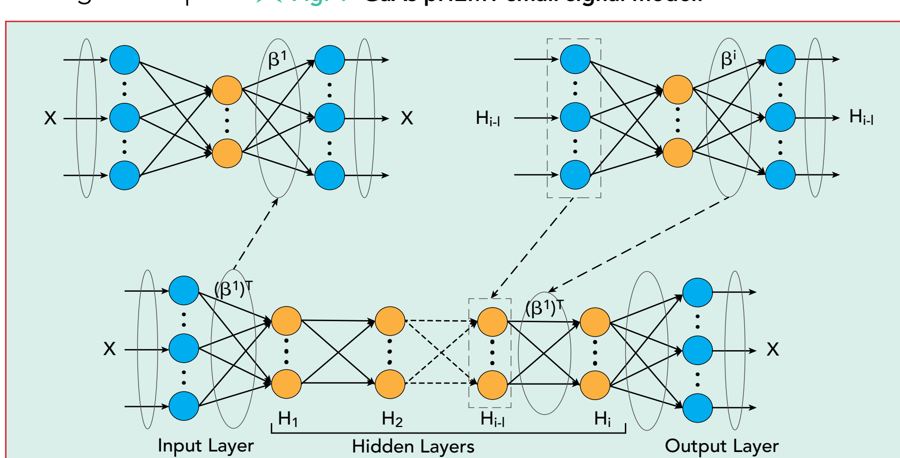
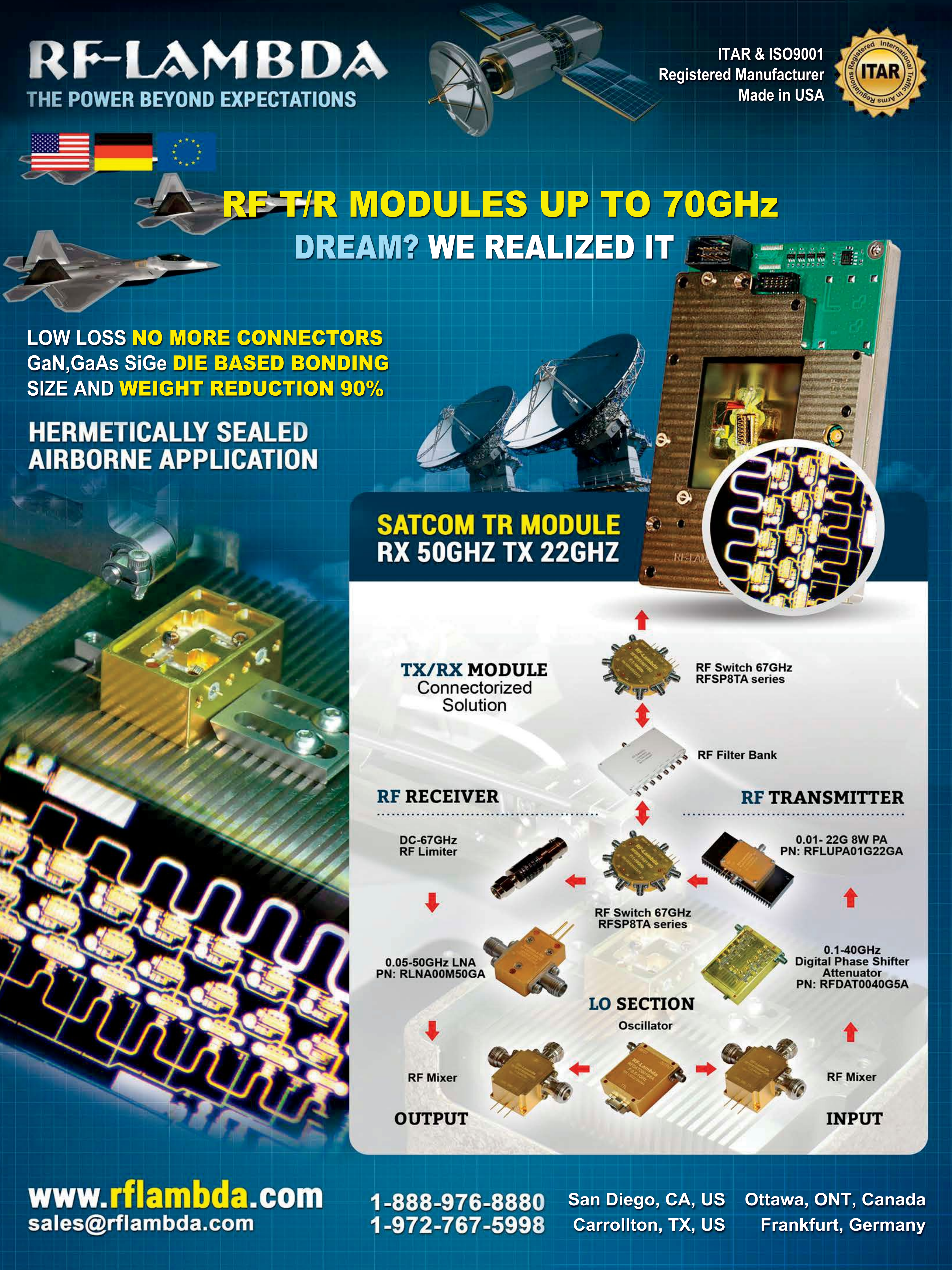


Fig. 2 DELM structure model.



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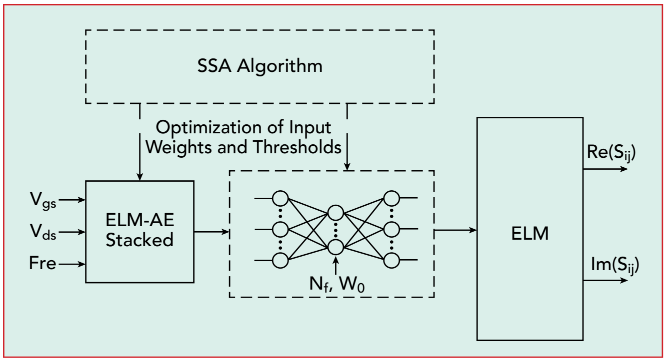

Fig. 3 **SSA-optimized architecture of the ELM applied to small-signal modeling.**

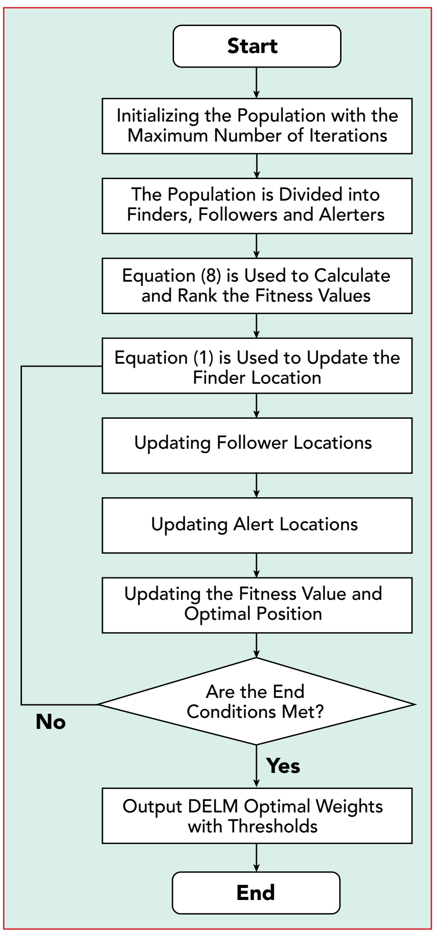

Fig. 4 **Flow chart of the SSA-DELM model.**

among individuals.

The role of sentinels within the community is equally crucial. Positioned at the edges of the group, they are responsible for monitoring potential threats, such as predators. Once danger is detected, sentinels quickly sound the alarm, guiding other sparrows to urgently move to safe areas, thereby enhancing the group's chances of survival. The presence of sentinels reflects the sensitivity to environmental feedback during the optimization process.

Sparrow Optimized DELM Algorithm

SSA-DELM, a DELM optimized by the SSA, is proposed for GaAs pHEMT small-signal modeling. DELM offers faster training speed and better generalization than other neural network methods. However, during the unsupervised pre-training phase of ELM-AE, the output layer's weight parameters are updated using least squares and the input layer's weights and biases are randomly generated orthogonal matrices. This randomness affects DELM's stability and precision across each ELM-AE.

To overcome this limitation and accurately model pHEMT device characteristics, especially with varying gate widths, the SSA is employed to optimize DELM's input weights and biases. ***Figure 3*** shows the proposed architecture for modeling device behavior. VGS, VDS and the frequencies of GaAs pHEMTs with different gate widths are the input variables for the ELM-AE stacking learning. The fingers and lengths correspond to the hidden layer elements of ELM-AE and the SSA optimizes the weights and thresholds. After unsupervised layer-by-layer training, the extracted high-level features are input into the final supervised ELM layer to fit the model. The final outputs are the real and imaginary parts of the modeled S-parameters.

Figure 4 shows the flowchart of the SSA-DELM algorithm. ***Equation 4*** is the fitness function, with T_{sim} representing simulated data and T_{test} representing measured data. The positions of finder, follower and alerter in the SSA are updated first. Then, the optimal position and fitness values are updated to determine if the minimum fitness value has been reached after a specified number of iterations. The DELM model receives the optimal weights and thresholds if the end condition is satisfied. Otherwise, the SSA continues to seek the global optimal solution.

$$fitness = \sum_{j=1}^{N} |T_{sim} - T_{test}| \qquad (4)$$

EXPERIMENTAL RESULTS

A 0.15 µm GaAs pHEMT transistor from WIN Semiconductors is used to verify the accuracy of the established small-signal model. S-parameters are measured from 2 to 50 GHz using an Agilent network analyzer. The model's robustness is evaluated with a 7:3 ratio of training to testing samples. The algorithm is run on an R5-5600 processor with 32 GB RAM.

To evaluate the SSA-DELM model's small-signal modeling, the modeling data of three neural networks with varying gate widths are compared. ***Figure 5*** through ***Figure 8*** show the results for four multi-finger GaAs pHEMTs with

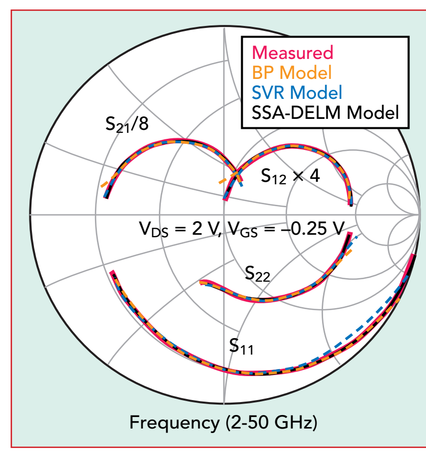

Fig. 5 **Modeled results of different neural networks for the device with a 4 × 25 µm gate width.**

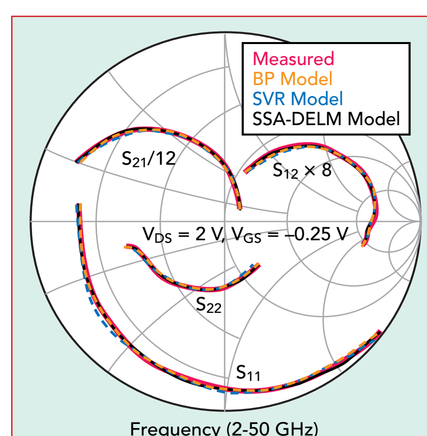

Fig. 6 **Modeled results of different neural networks for the device with a 4 × 75 µm gate width.**

0.15 µm gate lengths and different gate widths, comparing the neural networks' modeled S-parameters.

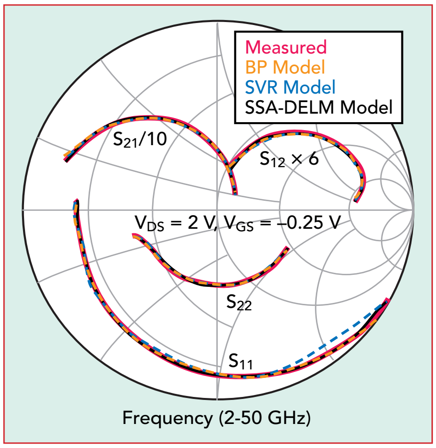

Fig. 7 **Modeled results of different neural networks for the device with an 8 × 25 µm gate width.**

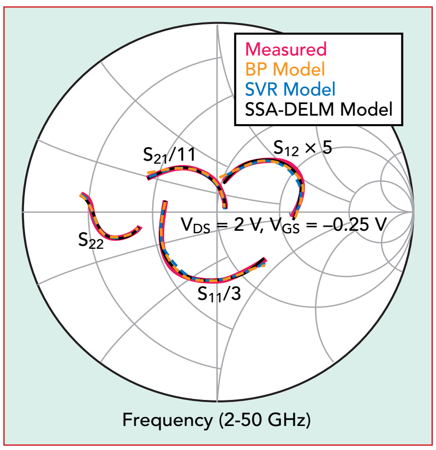

Fig. 8 **Modeled results of different neural networks for devices with an 8 × 75 µm gate width.**

For the 4 × 25 µm gate width, BP and SVR models show significant errors in the S_{11} low frequency and S_{12} high frequency ranges. At 4 × 75 µm, all three neural network models perform well. However, for the 8 × 25 µm and 8 × 75 µm gate widths, BP and SVR models perform poorly for low frequency S_{11}.

Figure 9 and ***Figure 10*** compare the 2 to 50 GHz S-parameter magnitude and phase modeling effects of the different methods with V_{GS} = -0.25 V and V_{DS} = 2 V. The proposed model shows some advantages, particularly in Figure 9a, where it models $|S_{11}|$ more accurately.

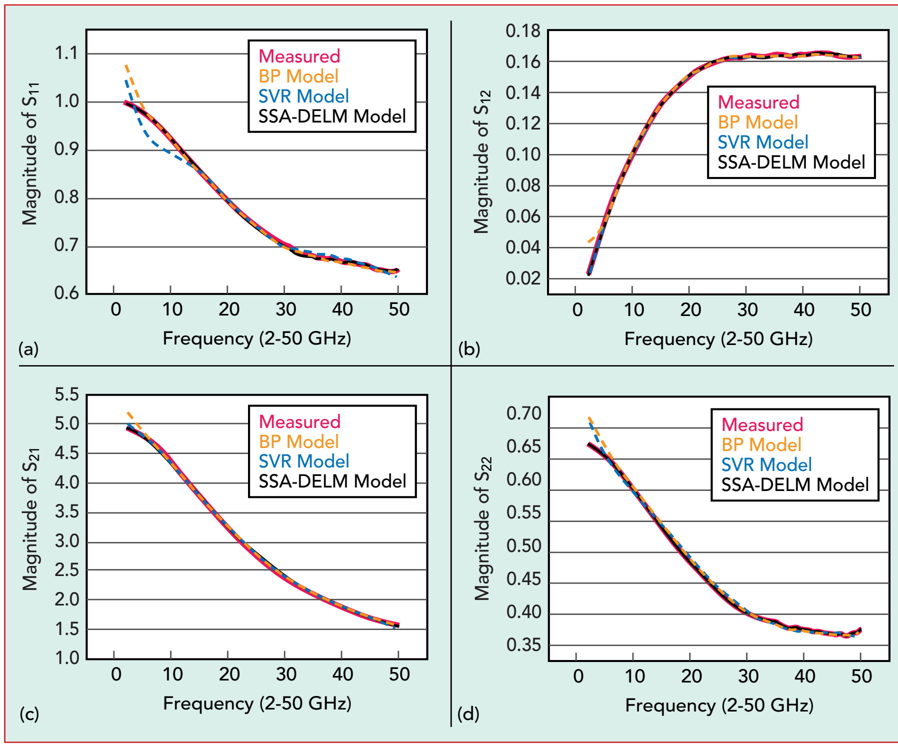

Fig. 9 **(a) $|S_{11}|$ results, (b) $|S_{12}|$ results, (c) $|S_{21}|$ results and (d) $|S_{22}|$ results.**

CONCLUSION

The small-signal modeling of GaAs pHEMTs with different gate widths is investigated to establish an accurate and fast modeling approach for microwave semiconductor devices with multi-finger

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DC~8.5	DC10-085 DC20-085	1.3	1.3	0.8	10±1.2 @0.5~8.5GHz	20±1.2 @0.5~8.5GHz	20 @0.5~8.5GHz
DC~12.4	DC10-124 DC20-124	1.3	1.5	1.0	10±1.3 @0.5~12.4GHz	20±1.3 @0.5~12.4GHz	20 @0.5~12.4GHz
DC~20	DC10-200 DC20-200	1.4	1.9	1.2	10±1.4 @0.5~20GHz	20±1.4 @0.5~20GHz	14 @0.5~20GHz
DC~26.5	DC10-265 DC20-265	1.5	2.2	1.4	10±1.7 @0.5~26.5GHz	20±1.7 @0.5~26.5GHz	13 @0.5~26.5GHz
DC~40	DC10-400 DC20-400	1.7	2.9	2.6	10±2.2 @0.5~40GHz	20±2.2 @0.5~40GHz	10 @0.5~40GHz
DC~50	DC10-500 DC20-500	1.8	3.5	2.1	10±2.2 @1~50GHz	20±2.2 @1~50GHz	8 @1~50GHz

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Way	Freq. Range (GHz)	P/N	Sum VSWR (:1) Max.	Distri. VSWR (:1) Max.	I. L.* (dB) Max.	Amplitude Unbal. (dB) Max.	Phase Unbal. (dB) Max.	Isolation (dB) Min.
2	DC~26.5	DP02-265	1.5 @0.5~26.5GHz	1.5 @0.5~26.5GHz	2.4	±0.4	±4	17 @0.5~26.5GHz
	DC~40	DP02-400	1.6 @0.5~40GHz	1.6 @0.5~40GHz	3.5	±0.4	±5	16 @0.5~40GHz
	DC~50	DP02-500	1.6 @1~50GHz	1.6 @1~50GHz	3	±0.5	±6	16 @1~50GHz
4	DC~26.5	DP04-265	1.6 @0.5~26.5GHz	1.6 @0.5~26.5GHz	5.2	±0.4	±6	16 @0.5~26.5GHz
	DC~40	DP04-400	1.6 @0.5~40GHz	1.6 @0.5~40GHz	7.5	±0.5	±7	15 @0.5~40GHz
	DC~50	DP04-500	1.7 @2~50GHz	1.7 @2~50GHz	4.4	±0.6	±8	16 @2~50GHz
8	DC~26.5	DP08-265	1.6 @0.5~26.5GHz	1.6 @0.5~26.5GHz	8	±0.6	±7	15 @0.5~26.5GHz
	DC~40	DP08-400	1.7 @0.5~40GHz	1.7 @0.5~40GHz	11	±0.6	±8	15 @0.5~40GHz
	DC~50	DP08-500	1.8 @1~50GHz	1.8 @1~50GHz	11	±0.9	±12	15 @1~50GHz

* Above Theoretical I.L.

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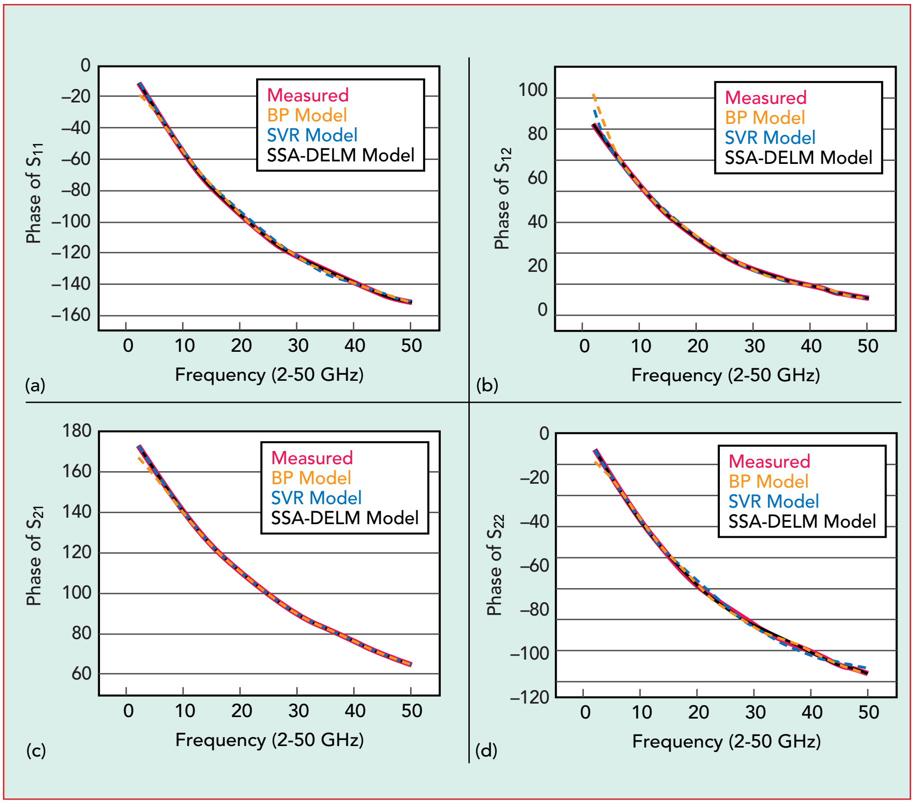


Fig. 10 (a) S_{11} phase results, (b) S_{12} phase results, (c) S_{21} phase results and (d) S_{22} phase results.

layouts. A deep learning-based modeling method optimized by the SSA is proposed to refine the random weights and thresholds. Experimental results show that the model achieves an accuracy of 99.7 percent, validating its effectiveness. This technique significantly improves accuracy compared to traditional BP and SVR modeling algorithms. This accuracy improvement is realized by eliminating the need to fine-tune neural network modeling parameters for cases with varying gate widths. ■

ACKNOWLEDGMENTS

This work was supported in part by the National Natural Science Foundation of China under Grant 61804046 and the Foundation of Department of Science and Technology of Henan Province under Grants 222102210172 and 21210221028.

References

1. A. Caddemi, E. Cardillo, S. Patanè and C. Triolo, "An Accurate Experimental Investigation of an Optical Sensing Microwave Amplifier," *IEEE Sensors Journal*, Vol. 18, No. 22, November 2018, pp. 9214-9221.
2. L. Y. Lee, Y. Wang and H. Wang, "A 25-31 GHz LNA in GaAs 0.15-µm pHEMT," *IEEE International Symposium on Radio-Frequency Integration Technology*, August 2021.
3. Z. Lv, Z. Xu and C. Song, "A Compact Model for Dual-Gate GaAs PHEMT and Application for Power Amplifier Design," *IEICE Electronics Express*, Vol. 18, No. 20, 2021.
4. F. Feng, W. Na, J. Jin, W. Zhang and Q. -J. Zhang, "ANNs for Fast Parameterized EM Modeling: The State of the Art in Machine Learning for Design Automation of Passive Microwave Structures," *IEEE Microwave Magazine*, Vol. 22, No. 10, October 2021, pp. 37–50.
5. J. Jin, F. Feng, J. Zhang, S. Yan, W. Na and Q. Zhang, "A Novel Deep Neural Network Topology for Parametric Modeling of Passive Microwave Components," *IEEE Access*, Vol. 8, May 2020, pp. 82273–82285.
6. G. B. Huang, Q. Y. Zhu and C. K. Siew, "Extreme Learning Machine: A New Learning Scheme of Feedforward Neural Networks," *IEEE international Joint Conference on Neural Networks*, July 2004.

Single-Chip Integrated Solution for Test and Measurement Demands

AMD
Santa Clara, Calif.

WHY T&M IN WIRELESS/RF IS IMPORTANT

Electronic test and measurement (T&M) for the RF/wireless market serves as the verification foundation for ensuring performance, interoperability, reliability, spectrum efficiency and regulatory compliance across the ecosystem of wireless technologies. This discipline enables technological innovations that impact multiple market sectors, from everyday consumer devices to sophisticated aerospace and defense systems.

Essential T&M instruments and systems, as shown in ***Figure 1***, include wideband spectrum analyzers and semiconductor automated test equipment (ATE). Wideband analyzers are used for visualizing RF signals, identifying interference and verifying design specifications, while ATE systems are used to verify functionality and performance of complex RF integrated circuits during manufacturing.

Modern wideband spectrum analyzers use advanced digital signal processing (DSP) combined with RF hardware and are used in wireless communications development, electronic surveillance and electromagnetic compatibility testing. ATE systems combine precise RF signal generation and analysis with digital test capabilities to evaluate mixed-signal devices like transceivers and systems on chips (SoCs). These systems are critical in ensuring quality in high volume semiconductor manufacturing.

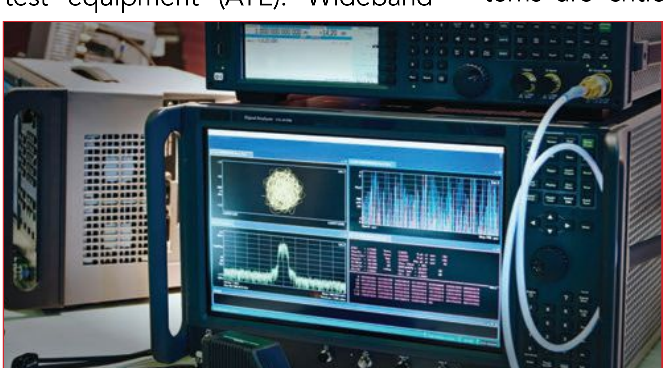


Fig. 1 **Example of scopes, signal analyzers and signal generators.**

NEXT-GENERATION REQUIREMENTS AND CHALLENGES

The evolution of next-generation wireless standards and the growth of high bandwidth applications drive the need for wider RF bandwidth spectrum analysis. This poses significant challenges for T&M systems, which must evolve to meet increasingly complex requirements.

Modern wireless systems are pushing toward multi-GHz bandwidths, particularly in mmWave and sub-THz applications. This necessitates T&M systems capable of capturing and processing unprecedented bandwidth in real-time. The challenge of processing a wider instantaneous bandwidth (IBW) involves designing high-speed RF data converters with sufficient resolution and implementing the massive DSP compute infrastructure required to handle the resulting data deluge.

The proliferation of multi-antenna, massive MIMO systems, beamforming technologies and high-throughput manufacturing tests are also driving increased demand for multichannel and synchronized testing. Next-generation T&M platforms must support a significant number of channels for testing multiple devices simultaneously to maximize test throughput and cost-per-test.

As wireless standards evolve,

T&M equipment must adapt to changes, necessitating programmable DSP platforms and reconfigurable analog RF front-ends that can accommodate emerging modulation schemes and test methodologies without becoming obsolete.

Finally, a challenging aspect of meeting next-generation wireless/RF T&M system requirements is accomplishing all these advances while maintaining reasonable power consumption and physical dimensions.

LIMITATION OF T&M SYSTEMS

Conventional T&M systems with stand-alone data converters and discrete field-programmable gate arrays (FPGAs) cannot meet next-generation RF/wireless testing demands due to two critical bottlenecks.

First, the expanding instantaneous bandwidth requirements (now in multiple GHz) create data throughput challenges. High-speed JESD204C interfaces between converters and processors introduce signal integrity issues, complex PCB routing, reliability concerns and increased costs. Second, processing these wider bandwidths exceeds single-FPGA capabilities, forcing multi-FPGA solutions that create timing challenges, development complexity and thermal hotspots. The overhead of inter-FPGA communication wastes power and resources. While ASICs offer better integration and efficiency, they sacrifice flexibility and increase costs.

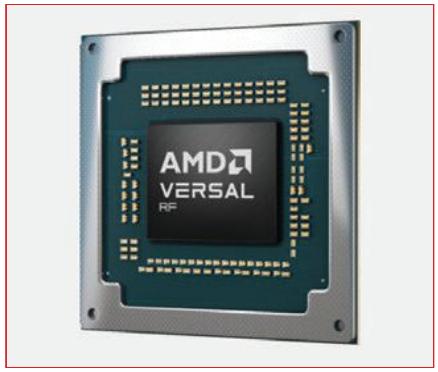


Fig. 2 The AMD Versal™ RF Series.

ADDRESSING T&M WITH A SINGLE-CHIP DEVICE

Next-generation T&M systems require innovations in converter-processor integration, signal processing architectures, compute for high performance per watt and throughput to meet testing demands of advanced wireless technologies.

The AMD Versal™ RF Series, as shown in ***Figure 2***, represents a paradigm shift in T&M system architecture, offering a single-chip monolithic solution by integrating data converters with heterogeneous computing resources, providing a platform designed for next-generation wireless testing.

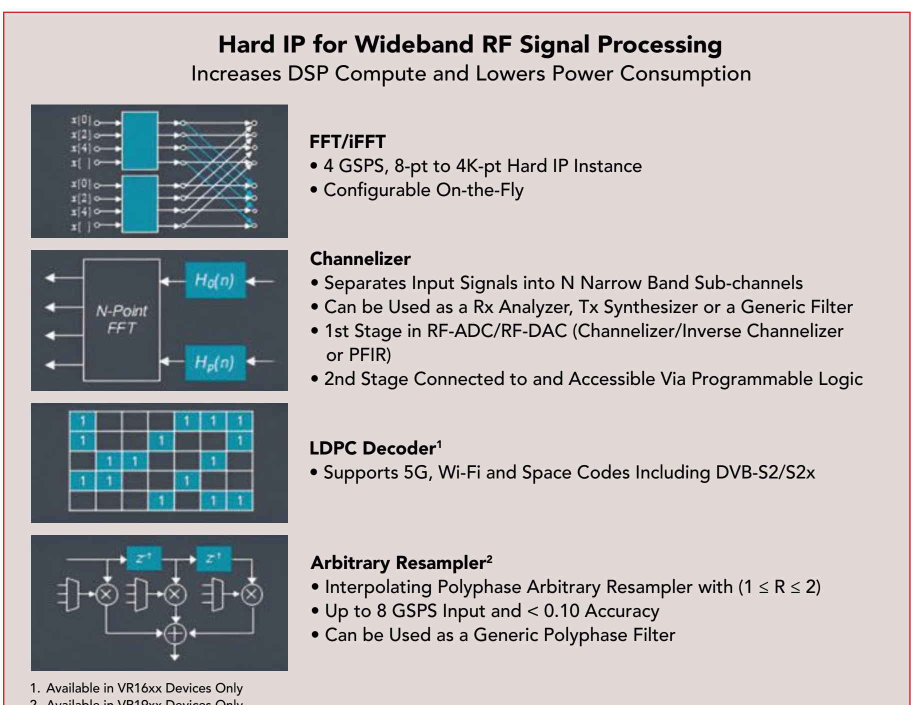


Fig. 3 Architecture of the AMD Versal™ RF Series.

Versal RF adaptive SoCs feature integrated 14-bit RF analog-to-digital converters (RF-ADCs) and RF digital-to-analog converters (RF-DACs) with built-in calibration capabilities that operate across a frequency range up to 18 GHz. This spectrum capability eliminates the need for multiple frequency conversion stages and external filtering. By integrating the converters into the SoC, Versal RF Series devices eliminate the need to use high-speed serial interfaces, which can reduce power consumption while simplifying board design. The scalable architecture supports various combinations of RF-DACs and RF-ADCs — up to 16 of each in a single package. This channel density enables multi-antenna testing, coherent multichannel applications and parallel device testing scenarios that would have previously required multiple discrete instruments or test modules. For semiconductor ATE applications specifically, this translates to higher throughput and lower cost-per-test. AMD Versal RF Series architecture, as outlined in ***Figure 3***, incorporates multiple instances of commonly-used DSP functions as hard IP blocks, providing improvements in compute throughput and performance per watt. For example:

- Configurable 8-point to 4K-point 4 GSPS FFT/iFFT hard IP blocks enable real-time spectrum analysis of input signals with minimal latency
- Dedicated programmable polyphase filter bank channelizers separate wideband input spectra into narrow subchannels, critical for analyzing modern multicarrier systems and can be used as generic FIR filters
- 8 GSPS configurable polyphase arbitrary resampler with up to 16,834 taps can be used as a generic polyphase filter

For flexibility and compatibility with existing IP, the programmable logic fabric includes DSP Engines (DSP58) supporting multiple data types, including single- and half-precision floating-point

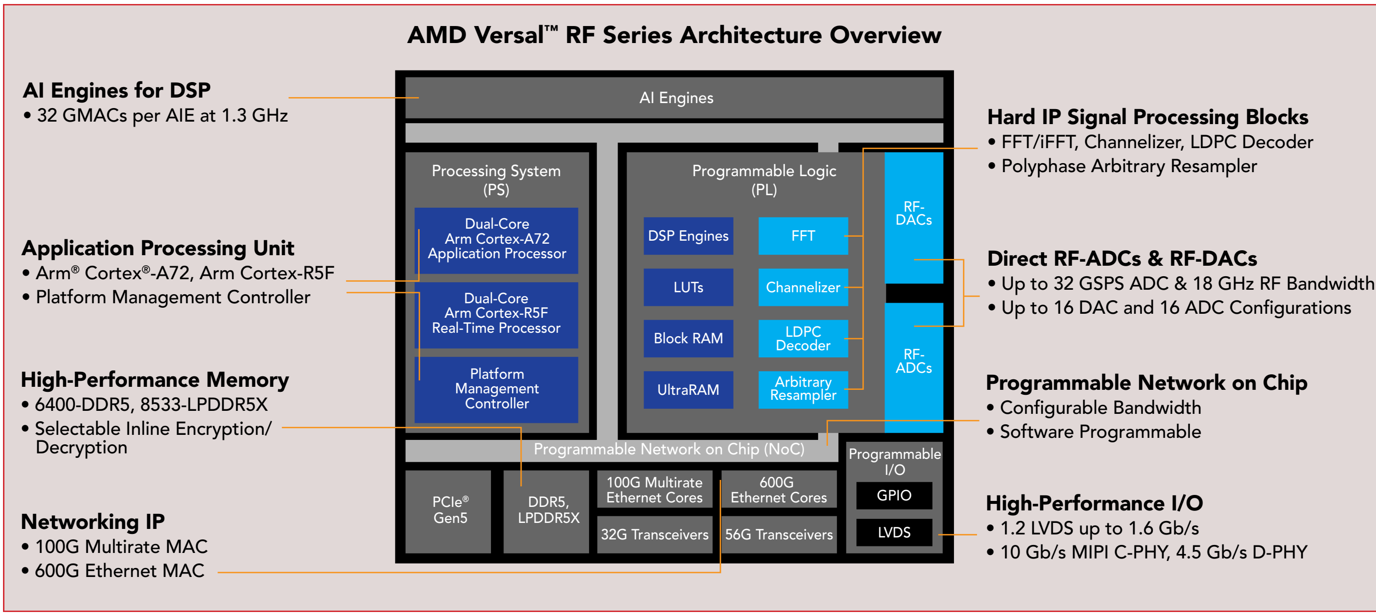


Fig. 4 The operating system.

and complex 18 x 18 operations. This programmable capability enables adaptation to evolving standards and custom processing requirements.

With AI expected to transform T&M with advanced signal identification, anomaly detection and optimization capabilities, the integrated AI Engines in the Versal RF adaptive SoCs operate directly at the analog front-end, performing both traditional DSP and AI/ML inferencing without external transfers. This enables real-time interference detection, signal classification and anomaly identification — transforming test capabilities through intelligent measurement adaptation.

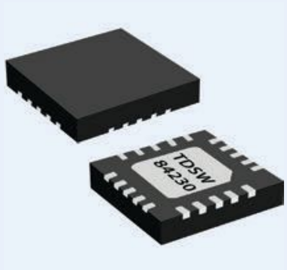
The architecture is complemented by a memory and I/O subsystem featuring LPDDR5X memory interfaces, 100G SerDes, 400GE networking and PCIe® Gen5 connectivity. This infrastructure, as demonstrated in ***Figure 4***, supports the data movement requirements of modern test systems while maintaining interoperability with host systems and test environments.

SUMMARY

Next-generation T&M systems need new architectures to address the requirements and challenges of ever-increasing RF bandwidth. AMD Versal RF devices integrate RF data converters, traditional FPGA programmable logic, dedicated DSP hard IP blocks and AI Engines to provide a flexible single-chip solution for the RF/wireless T&M market.

AMD
Santa Clara, Calif.
www.amd.com

GaN High-Power Switch Up to 5 GHz



Teledyne HiRel Semiconductors introduced its latest product, the GaN high-power RF switch, model TDSW84230EP. This switch is designed to replace positive-intrinsic-negative (PIN) diode-based RF switches commonly used in the RF front-ends of modern tactical and military communication radio systems. Utilizing a wide bandgap GaN high electron mobility transistor (HEMT) process, the TDSW84230EP offers excellent breakdown voltage and saturation current capabilities. It is housed in a 16-pin quad-flat no-lead (QFN) 3 x 3 x 0.8 mm plastic surface-mount package and is qualified for operation within a military temperature range of -55°C to 125°C.

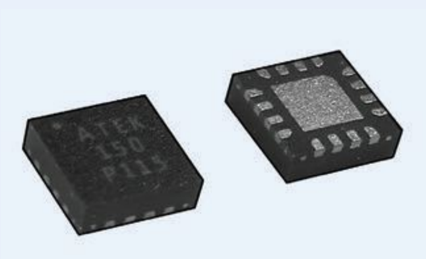
The TDSW84230EP is a single pole double throw GaN reflective switch that employs MMIC design techniques. It supports a 20 W continuous wave power handling capability and operates across a frequency range from 30 MHz to 5 GHz. With an insertion loss of 0.2 dB and port isolation of 45 dB, this switch offers efficiency and board area savings compared to traditional PIN diode architectures.

Optimized for aerospace and defense applications, the TDSW84230EP is designed to meet the demands of wideband continuous operation in defense software-defined radio architectures. This high-power GaN switch provides a solution for replacing traditional PIN diode switches, offering tolerance for up to 900 mA/mm saturation currents and voltage RF power handling capabilities. The inherent high breakdown voltage and carrier density of GaN technology enable higher operating power capabilities while increasing linearity to support better harmonic and spurious signal requirements.

The TDSW84230EP devices are now available for order and shipment in commercial versions from Teledyne HiRel Semiconductors or authorized distributors. They are shipped from Teledyne's Department of Defense Trusted Facility in Milpitas, Calif.

Teledyne Aerospace & Defense Electronics | Teledyne HiRel Semiconductors
Milpitas, Calif.
www.teledyne-ade/HiRel-Semiconductors

Wideband LNA MMIC Operates to 8 GHz



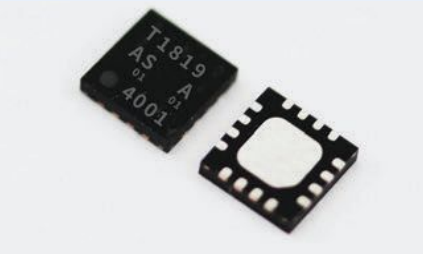
ATEK Midas, a designer and supplier of high performance, mixed-signal silicon ASICs and RFICs and GaAs and GaN MMICs, introduces the ATEK150P3, a 10 MHz to 8 GHz low noise amplifier (LNA) MMIC in a 3 x 3 mm QFN SMT package. The ATEK150P3 LNA provides 21 dB of flat gain and a noise figure of 1.5 dB from a single +5 V DC supply voltage, enabling users to realize wideband receiver front-ends. With a P1dB of +18 dBm and an OIP3 of +32 dBm, the ATEK150P3 offers excellent drive and linearity for a wide range of IoT, radar, SDR, test instrument and EW/ECM applications. Low frequency operations can be extended below 10 MHz by increasing the values of the external DC blocking capacitors and RF choke. RF inputs and outputs are matched to 50 Ω. ATEK150P3 MMIC LNA products and evaluation boards are available from stock.

ATEK Midas applies expertise, creativity and passion to design analog and mixed-signal silicon ASICs and RFICs, along with GaAs and GaN MMICs and modules for aerospace, automotive, 5G/6G telecom, data center, defense, industrial/IoT, medical, scientific and test and measurement markets. ATEK works with customers to provide focused, custom IC design and development services that deliver IP blocks to engineering prototypes and turn-key production solutions. These solutions are complemented by ATEK's line of MMIC standard products for communication and sensor applications, extending up to 100 GHz.

ATEK's North American sales and applications partner, ViNo Waves LLC, works closely with ATEK technical representatives to provide sales, marketing and technical support. ViNo Waves can be reached at sales@vinowaves.com.

ATEK Midas
Istanbul, Türkiye
info@atekmidas.com

For further information, contact Norm Hildreth
+1 781-789-8454
sales@vinowaves.com



SPDT Switch for Base Station Applications

Nisshinbo Micro Devices has launched the single pole double throw (SPDT) switch NT1819, designed for 5G infrastructure. It supports the sub-6 GHz band from 3.3 to 5.0 GHz and delivers isolation performance exceeding 60 dB within a 3.0 x 3.0 mm package.

This isolation performance reduces interference between adjacent components in 5G base stations, an advantage for applications such as digital predistortion signal combining. A built-in 50 Ω absorptive termination ensures impedance matching regardless of the switch state, which helps suppress signal reflection and improve system stability.

In addition to the isolation performance in the main 5G frequency bands, NT1819 features a frequency range from 0.2 to 7.125 GHz, insertion loss between 0.7 and 1.2 dB and a switching speed of 250 ns. It also operates reliably across a temperature range from -40°C to +105°C, ensuring performance in various deployment environments. With these attributes, this product is well-suited for a wide range of next-generation communication systems applications, including Wi-Fi and unlicensed communications in the U.S. Its packaging and performance support the miniaturization and integration trends guiding modern RF systems.

In addition to device supply, Nisshinbo offers advanced solution services for module manufacturing. These include bare-die mounting techniques that enable direct integration onto substrates or carriers, thus streamlining the production process and reducing space and cost.

Nisshinbo Micro Devices, Inc.
Tokyo, Japan and
San Jose, Calif.
www.nisshinbo-microdevices.co.jp/en/

MAKING WAVES

Adoption of AI and O-RAN in the Telecoms Sector

Mobile World Live: Industry Insights with Bryan Goldstein - ADI's Corporate Vice President of Aerospace, Defense and Communications.

Analog Devices

www.analog.com/en/resources/media-center/videos/6369637039112.html

G.T. Microwave Celebrates 30 Years

G.T. Microwave, Inc. commemorated its 30-year anniversary on March 20, 2025. G.T. Microwave has achieved year-over-year growth and profitability, serviced global markets, visibility in major defense and commercial projects and spear-headed leading-edge product innovations.

G.T. Microwave, Inc.

https://gtmicrowave.com

Micro-Coax Launches New Website

The brand-new Micro-Coax website showcases the company's expansive product offerings and resources, providing customers with a seamless, comprehensive approach to finding the most advanced signal transmission technologies.

Micro-Coax

www.micro-coax.com

Fundamentals of Measuring Wideband RF Signals

Check out Mini-Circuit's blog post covering the move towards and how to measure wideband RF signals.

Mini-Circuits

https://blog.minicircuits.com/fundamentals-of-measuring-wideband-rf-signals

Discover Safran in 2 Minutes!

Key figures, markets, ranking... Find out all about the Group's corporate ID in two minutes flat!

Safran

www.youtube.com/watch?v=-G-EpFS-mYI

VNA400 Features & Specifications

In this video, learn about Signal Hound's VNA400, a compact powerhouse revolutionizing RF testing.

Signal Hound

www.youtube.com/watch?v=q4IxcF-1zjw

NEW PRODUCTS

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

DEVICES COMPONENTS/MODULES

Low-cost Switched Filter Banks

VENDORVIEW

Switched filter banks (SFB) can have 2 to 6 channels and operate from 0.1 GHz to 6.0 GHz in SMT or connectorized housings. Low insertion loss is 1:0 to 3.0 dB typically, return loss is 12 dB minimum, isolation is 22 to 60 dB, power supply is 5 VDC, switching speed is 135 ns typically. Prices are as low as $250 for production quantities. Please note, this does not obsolete 3H robust SFBs with an operating range from 0.1 to 18.0 GHz, including high power options.

3H Communications
www.3hcommunicationsystems.com

Waveguide Gaskets

VENDORVIEW

Fairview Microwave has launched a new line of waveguide conductive gaskets. These gaskets are designed to ensure superior conductivity and reliable sealing for various waveguide sizes and flange configurations, meeting the rigorous demands of RF and microwave engineers across aerospace, telecommunications and defense industries. Fairview Microwave's new waveguide gaskets are engineered for optimal performance with a variety of waveguide sizes.

Fairview Microwave
www.fairviewmicrowave.com

DC~70 GHz Precision Fixed Attenuators & Terminations

VENDORVIEW

MIcable launched DC~40 GHz precision attenuators and DC~70 GHz precision terminations, with accurate attenuation and excellent VSWR. They are with passivated stainless steel (except SSMP type) and have features of ultra-low leakage, superior shielding effectiveness and high reliability. The precision attenuators/terminations are good for the applications of microwave/millimeter systems, various test systems, RF laboratory etc.

MIcable Inc.
www.micable.cn

High Performance Low-Cost 1:1 5 MHz - 2000 MHz Balun

The MRFXF0102 is a high performance, low-cost 1:1 Balun that operates from 5 MHz to 2.0 GHz. It was developed specifically for the Qorvo QPC -733x line of variable attenuators output balun and is a true "drop-in" per MiniRF testing. The MRFXF0102 has excellent return loss, low insertion loss and provides repeatable performance over broad temperature range. It's offered in the industry std .150 × .150 surface-mount S20 package. The part includes MiniRF Inc. unsurpassed reliability with 100 percent RF tested devices.

MiniRF
www.minirrf.com

16-channel Attenuator Box

Ranatec announced its 16-channel Attenuator Box. With 16 individual digitally controlled attenuators for high dynamic signal level adjustment, the Attenuator Box is ideal for transmission loss simulation, signal fading and MIMO measurements. It can be combined with Ranatec butler matrices, RI 3041 and RI 3101 or Ranatec switching boxes and can be used for any type of automized test set-up. It is controlled via Ethernet by different APIs or web-interface.

Ranatec
www.ranatec.com

Wideband Bias Tee

Sigatek introduced a new 2.92 mm connectorized bias tee offering high performance over the ultra-broadband frequency range of 10 kHz to 40 GHz. This bias tee offers a flat loss response of 2.2 dB across the frequency band and current rating is 400 mA with 50 VDC. Isolation is greater than 30 dB typical and return loss is greater than 12 dB. Applications are for emerging designs, test and measurement, 5G, 6G, radar, mmWave and more.

Sigatek LLC
www.sigatek.com

CABLES & CONNECTORS

SMA Connectors

Amphenol RF introduces new high performance SMA connectors suited for use with versatile high frequency 0.81 mm cable or 1.32 mm double shielded cable. These SMA plugs feature a threaded coupling mechanism ensuring a secure connection even in rigorous applications. The connectors are tested for up to 500 mating cycles, guaranteeing durability and reliability. The 165°C maximum temperature range ensures unrelenting performance in harsh conditions where temperature resistance is crucial. Preconfigured cable lengths and custom cable assemblies are available upon request.

Amphenol RF
www.amphenolrf.com

Quick-Turn Customized RF Test Cables

VENDORVIEW

ConductRF announced the expanding availability of its Quick-Turn customized RF test cables, optimized for high frequency performance in production and lab test environments. These assemblies feature robust electrical stability, rugged durability and fast delivery — available in lengths up to 10 m or 30 ft. Each assembly is built to order and 100 percent electrically tested to ensure consistency and performance — a critical factor for test applications where cable integrity directly affects DUT validation.

ConductRF
www.conductrf.com

RF Angled PCB Connectors in 3 Sizes

VENDORVIEW

Pasternack announced the launch of its new RF angled PCB connectors. Designed to meet the growing demands of RF applications, these connectors are now available in 1.85 mm, 2.4 mm and 2.92 mm series. Traditionally, Pasternack has offered straight or edge-mount PCB connectors, but this new angled design delivers increased flexibility, especially for prototyping and testing.

Pasternack
www.pasternack.com

Expansion of Cable Harness Production Capacity

Smiths Interconnect announced the expansion of its cable harness production capacity at its facility in Tunisia. This strategic move is aimed at meeting the growing demand for high-quality cable harness solutions across various industries and strengthening Smiths Interconnect's product offering with an investment for growth in support of all EMEA production sites. A cable harness is an assembly of electrical cables or wires which are bound together to transmit signals or electrical power.

Smiths Interconnect
www.smithsinterconnect.com

AMPLIFIERS

Broadband Amplifier Covers 50 to 95 GHz

VENDORVIEW

SBB-5039532510-1F1F-S1 is a 1 mm broadband amplifier with a typical small-signal gain of 25 dB, a nominal P1dB of +10 dBm and a typical noise figure of 7.0 dB across the frequency range of 50 to 95 GHz. The DC power requirement for the broadband amplifier is +8 VDC/300 mA. The use of a heat sink is advised to assist in cooling the device. The RF connectors are female 1 mm connectors. Other port configurations are available under different model numbers.

Eravant
www.eravant.com

800 – 3000 MHz, 350 W High Power Amplifier

VENDORVIEW

The AMP20067 operates from 800 to 3000 MHz, delivering 350 W output and 300 W minimum P1dB. It features Class A Linear design with high-power advanced technology for instantaneous wide bandwidth. AMP20067 includes built-in protection circuits, extensive monitoring and a large color-touchscreen with remote flexible interfaces. Ideal for EMI/RFI, lab, CW/Pulse and communications applications, the high power amplifier has high efficiency with unprecedented reliability and ruggedness in a 5U chassis.

Exodus Advanced Communications
www.exoduscomm.com

SYSTEMS

New SOSA Aligned ATR Enclosures

Utilizing the 3U OpenVPX form factor, the various chassis platforms typically support 100GbE or higher speeds. The new ARINC 404 5/8 size ATRs from Pixus feature customized I/O options and various SOSA slot profile options, including RF and optical interfaces through the backplane. For chassis management, the ATR has the option of implementing Pixus' SOSA aligned Tier 3 mezzanine-based solution that sits behind the backplane. This saves a slot of space while acting as a health monitor and control module for the system.

Pixus Technologies
www.pixustechnologies.com

SOURCES

AXTAL's OCXOs

Q-Tech Corporation announced the availability of the AXIOM line of ultra-low noise oven-controlled crystal oscillators (OXCOs). Designed and manufactured by Q-Tech's German affiliate, AXTAL, the benefits of the AXIOM OCXOs ultra-low phase noise (close-in and noise floor) are higher resolution for radar systems, better quality and more transmissible information for communications systems and improved accuracy and lower measurement limits for RF measurement systems. They also reduce jitter, an important consideration in these applications.

Q-Tech Corporation
www.q-tech.com

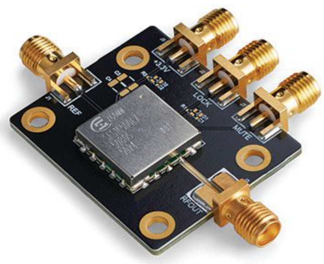
Ultra-Rugged Precision: SiT5348 Super-TCXO for Aerospace and Defense

VENDORVIEW

Engineered for mission-critical aerospace and defense systems, the SiTime Endura™ SiT5348 MEMS Super-TCXO delivers ±50 ppb stability from –40°C to +105°C and acceleration sensitivity down to 0.009 ppb/g. Withstanding > 30,000 g shock and offering digital, voltage-controlled or fixed-frequency options, it ensures reliable performance in extreme environments. Ideal for missiles, SATCOM, GNSS and ruggedized networks, the SiT5348 integrates on-chip regulators and supports frequency pulling down to 5 ppt resolution. Now available from RFMW.

RFMW
www.rfmw.com

Custom Frequency Phase Locked Oscillators



The new SFSLX product line is a phase locked product platform providing RF and microwave engineers with an accelerated product development. This first of its kind program allows a quick and easy way for engineers to configure a phase locked oscillator to their frequency specifications. Through an easy online ordering system, the engineer selects any output frequency from 50 MHz through 22.5 GHz, in a resolution of 0.1 Hz and specifies their reference frequency input from 5 to 200 MHz.
Z-Communications
www.zcomm.com

TEST & MEASUREMENT

Value Series VNAs

VENDORVIEW

Copper Mountain Technologies released the Value (V) Series vector network analyzers (VNAs). The V Series will include three 2-port, 2-path measurement models, V0402 4.5 GHz VNA, V0602 6.5 GHz VNA and V0902 9 GHz VNA. All models have a starting frequency of 100 kHz. These VNAs deliver highly accurate measurements with the ideal feature set for many production and field service applications in a cost-effective package. The V Series is an upgraded replacement of the M Series VNAs.
Copper Mountain Technologies
www.coppermountaintech.com

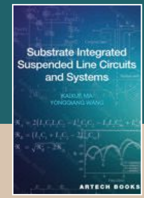
InsightPro Software Platform

Maury Microwave launched InsightPro™ — their next-generation unified software suite designed to accelerate measurement and modeling workflows across R&D, design verification/validation and small-scale production. As the full replacement to legacy software, InsightPro enables customers to stay ahead in the fast-paced world of wireless technology development, where precision, efficiency and confidence in measurement data are critical to success. Built with a measurement-first approach, InsightPro streamlining data collection, management and analysis, serving as the primary software interface for instrument-agnostic small-signal and large-signal characterization.
Maury Microwave
www.maurymw.com

Vector Network Analyzer

Signal Hound announced the release of the highly anticipated VNA400 to its expanding product line. This high performance, USB-powered vector network analyzer (VNA) is in stock and available to order now. The 2-port, 40 GHz VNA400 utilizes a combination of high dynamic range and ultra-fast measurement to unlock data-rich, system-level analysis. The VNA400 boasts a wide range of capabilities, making it a perfect fit for the lab, the manufacturing facility or out in the field. A fully featured VNA software suite is included with this product.
Signal Hound
www.signalhound.com

Reviewed by: Dr. Ajay K. Poddar



Bookend

Substrate Integrated Suspended Line Circuits and Systems

Kaixue Ma and Yongqiang Wang

This book explores the substrate integrated suspended line (SISL), an innovative transmission line technology with broad applications. It covers the fundamental principles, structural design and key characteristics of SISL, while offering detailed discussions on its use in passive circuits, active circuits and front-end subsystems. With a focus on RF, microwave and mmWave circuits and systems, the text systematically introduces core concepts and practical implementations.

This book is designed for a wide range of readers involved in the design and development of electronics for modern wireless communication systems. Its exploration of SISL-inspired printed resonators, with a focus on complex design trade-offs like resonator quality factor and oscillator phase noise performance, makes it particularly valuable to professionals working in sectors including signal source development for next-generation communication systems, radar, IoT and autonomous vehicle systems.

One highlight is the book's inclusion of case studies showcasing successful implementations in oscillators, radar systems, wireless communication devices and satellite communication. These case studies not only demonstrate the versatility of SISL circuits but also provide insights into how these systems perform in actual applications, further reinforcing the book's relevance.

Another standout feature is the comprehensive coverage of SISL manufacturing and fabrication techniques. The authors provide a deep dive into PCB fabrication, etching and assembly processes, along with the challenges that arise when working at higher frequencies. This section helps bridge the critical gap between circuit design and actual implementation, ensuring that professionals can transition from conceptual designs to functional, high performance systems.

Unlike many resources that focus on isolated aspects of microwave technology, this book provides a comprehensive and detailed structure, with seven chapters that explore the full spectrum of SISL applications. Each chapter offers both technical depth and accessibility, making it a valuable reference for researchers, engineers, scientists, academics and students involved in advanced microwave and RF technologies. up on the theory behind the practice.

ISBN: 9781685690298
Pages: 296

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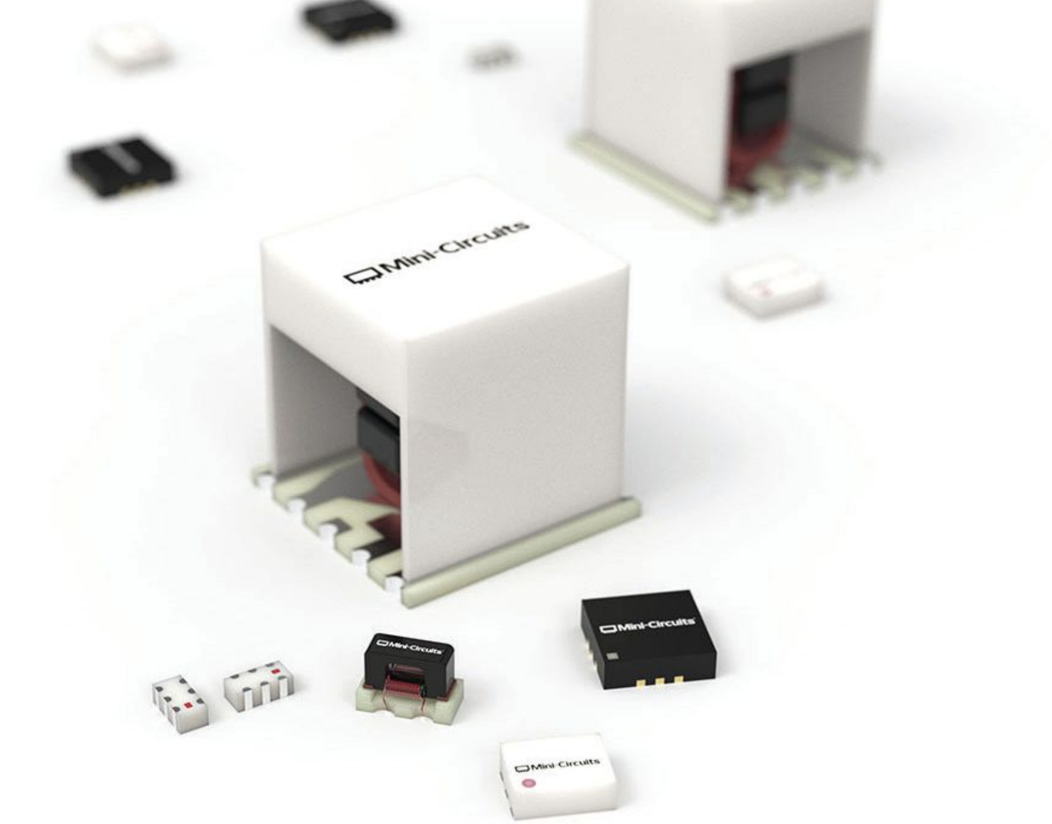

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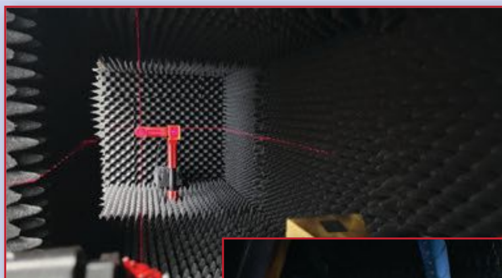

Gerard James Hayes founded the independent, nonprofit research institution WRC in 2010. Formally known as Wireless Research Center of North Carolina, WRC has become a technical center of excellence for applied research, engineering and certified testing. WRC has three initiatives – WRC Technologies, RIoT and DigitalBridge. WRC Technologies is a leading provider of strategic engineering services focusing on antenna, RF and wireless technologies from small wearable devices to high-reliability wireless systems. Because they do not require a share of jointly developed intellectual property, WRC Technologies fosters collaboration between industry, academia and research on a global scale. RIoT focuses on creating a collaborative ecosystem for companies from single-person startups to multi-national corporations. DigitalBridge provides accessible technology and training to local communities.

WRC is headquartered in North Carolina. From this focal point, WRC makes a global impact by developing IP and encouraging collaboration between industry, government and academia. WRC Technologies contributes to all stages of development from initial concept to high volume production. The engineering services include RF and antenna design, simulation, prototyping, verification, optimization and testing. WRC Technologies has a broad range of wireless engineering expertise, including IoT, consumer electronics, healthcare, industrial, telecom, aerospace, government and public safety. Supported technologies include mmWave, satellite and other communication protocols.

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DigitalBridge, a workforce development initiative of WRC, is designed to close the digital skills gap by providing accessible technology training and career development services to underserved communities. DigitalBridge offers participants mentorship, coaching and job search assistance. DigitalBridge partners with businesses to design targeted training programs that align with current labor market demands, equipping participants with the digital competencies required to access local and remote employment opportunities.

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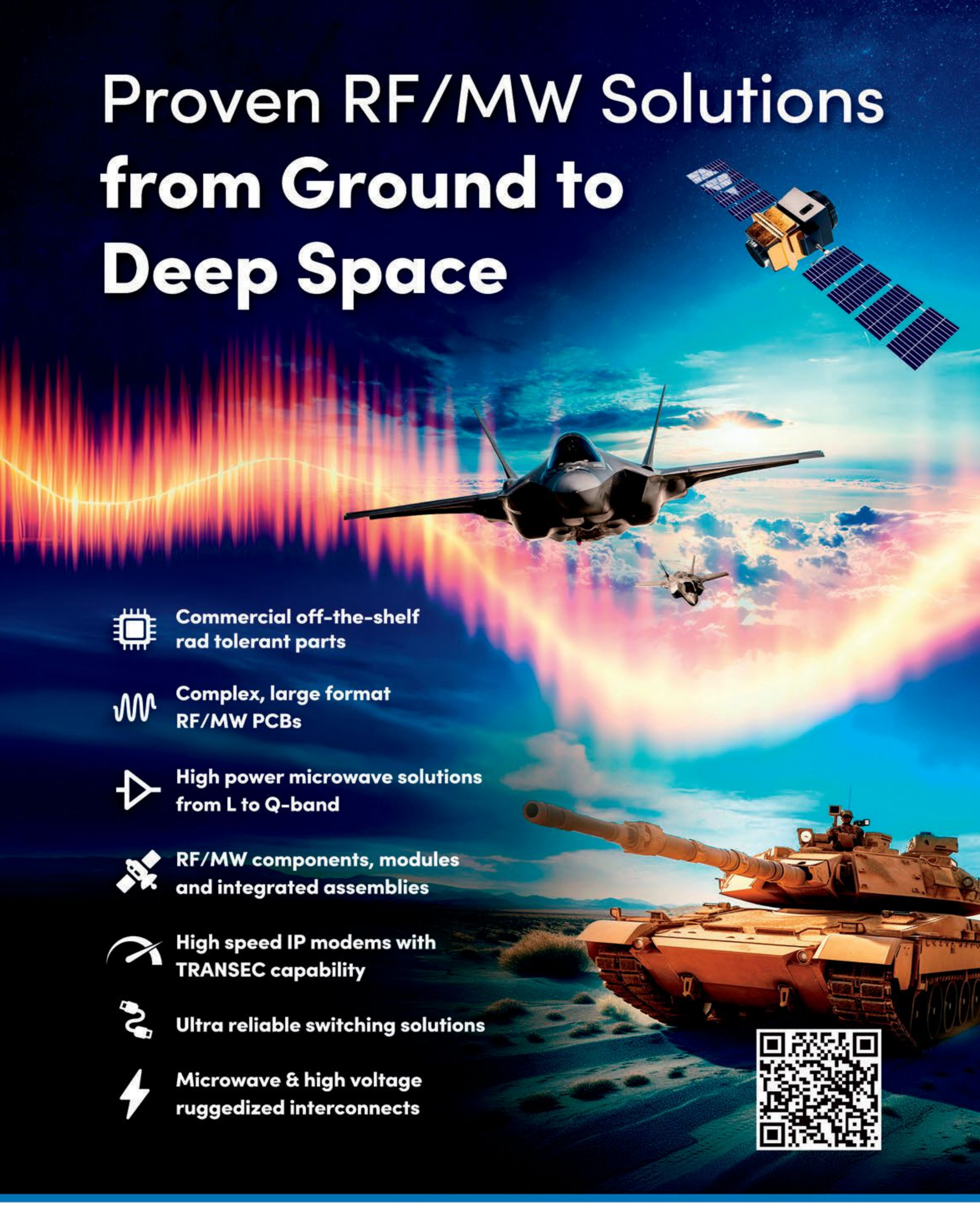
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Applications of RF-over-Fiber Technology in the Defense and Civilian Markets

Oz Abramson, David Gabbay and Avner Sharon
RFOptic, Petah Tikva, Israel

RF-over-Fiber (RFoF) technology is transforming the landscape of signal transmission systems by offering a wideband transport capability for RF signals between antennas and control locations. This article highlights the key advantages of RFoF technology, which include signal integrity, immunity to electromagnetic interference (EMI), high bandwidth capacity, reduced size and weight, environmental resistance and enhanced security. These features position RFoF as an attractive solution across a diverse set of applications in both defense and civilian markets.

In defense applications, RFoF technology plays a critical role in comprehensive remote sensing, secure communications and surveillance systems. Such systems can be hardened against external interference, preventing damage to sensitive equipment from electromagnetic pulse scenarios. Applications extend to remote antenna ground stations for drone controllers and "virtual air" radio interconnect, which securely connects large numbers of radios in physically separated trainers, such as flight simulators, avoiding emitting interference and unwanted surveillance. Phase-matched multichannel RFoF technology enables the remote operation of direction-finding antenna arrays. Combining RFoF with optical delay fiber segments creates optical delay lines (ODLs). Radar and altimeter calibration and testing using ODLs enhance radar detection accuracy by providing accurate distance simulation through stable, selectable time delays of the radar RF signal. Target simulators validate the full scale of radar detection abilities by combining many spatially separated emitters with ODL RFoF technology.

In the civilian market, RFoF technology is crucial for 5G cellular network performance and interoperability tests, providing solutions to meet the frequency and bandwidth demands of emerging technologies such as 6G. It also extends Global Navigation Satellite System (GNSS) applications to sheltered areas, ensures reliable communication in the mining industry and enables range extension of distributed antenna systems (DAS). The technology supports astronomy research in radio telescope observatories with long-distance, wideband and phase-stable RF signal transmissions linking the Very Long Baseline Array and interferometric antenna arrays.

ADVANTAGES OF RF-OVER-FIBER TECHNOLOGY

RFoF technology is a new approach in transmitting RF signals between antennas and control locations. It is a small-signal, wideband transmission technology that handles signal levels typically under +20 dBm. The key advantages include:

Signal Integrity: RFoF systems deliver signal transmission over extended distances that are greater than those that coax cables can sustain. This is crucial for applications such as radar, communication and surveillance where signal fidelity is vital.

Immunity to EMI: Fiber optics are not affected by EMI, making them ideal for environments rich in electronic noise, such as military installations and urban areas. Single-mode optical fibers are essentially glass conduits that carry the signal in a cross section that is 9 μm in diameter. It is difficult to disrupt this optical transmission by induced EM radiation. Running fiber into sheltered areas is safer than using coaxial cables, as EM radiation can be induced on a coax cable and conducted into the sheltered compound.

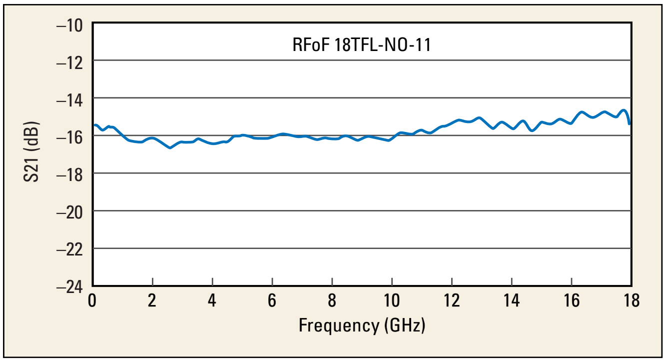


Fig. 1 Insertion loss of an RFoF link without amplifiers.

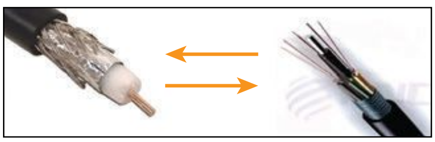


Fig. 2 Fiber cable construction versus coaxial cable construction.

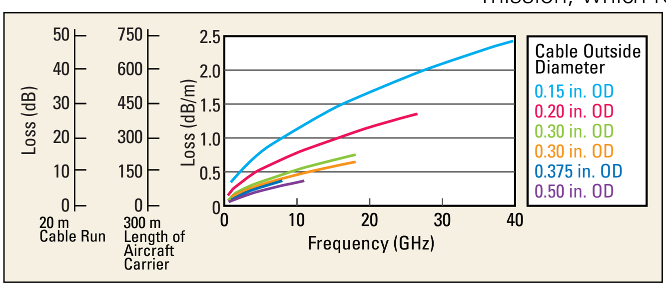


Fig. 3 Coaxial cable versus frequency for various outside diameters.

Fig. 4 Progressive ODL.

Bandwidth Capacity: RFoF can accommodate large volumes of data at high frequencies, enabling the simultaneous operation of wideband or multiple frequency-division channels with minimal degradation. Each RFoF link can deliver flat signals with bandwidths exceeding 40 GHz over distances ranging from a few meters to many miles. For comparison, a good 50-meter RF cable develops an insertion loss slope of approximately 5 dB over a bandwidth of 1 MHz to 1 GHz. ***Figure 1*** illustrates the typical insertion loss and flatness of an 18 GHz RFoF link without amplifiers.

Size and Weight: Fiber-optic cables are lighter and less bulky than traditional coaxial cables. Single and multiple fiber strands can transport nearly unlimited amounts of RF signals and data at a minimal cost. This enhances deployment flexibility in defense scenarios, particularly for surveillance sensors, electronic warfare (EW) transponders and drones that use expendable interconnect fibers. ***Figure 2*** shows a view of a fiber cable containing multiple fiber strands versus the construction of a coaxial cable.

Power Consumption: RFoF links consume a couple of watts per pair and compare favorably with coaxial transmission, which requires booster power amplifiers between short cable intervals. In a 60-meter application transporting an 18 GHz bandwidth RF signal, the RFoF link requires about 5 W, while a comparable coaxial transmission requires about 25 W to power the amplifiers that recondition the signal at 15-meter intervals.

Environmental Resistance: Optical fibers are resistant to moisture, chemicals and extreme temperatures, reducing the need for shielding compared to RF coaxial cables.

Enhanced Security: Fiber optics offer a higher level of security against eavesdropping and signal interception because of their confined transmission properties. In addition, splicing into existing fiber networks can be easily detected.

These advantages position RF-over-Fiber technology as a solution for various defense and civilian applications. For example, a 1000-meter section of a single-mode fiber transmits a 20 GHz RF signal with an insertion loss that is 7500x lower than the loss of the same length of 0.15 in. diameter coaxial cable. ***Figure 3*** illustrates the insertion loss per meter versus frequency for various coaxial cable diameters. The scales on the left-hand side of Figure 3 also illustrate how this translates to total loss over a 20-meter cable run, as well as the loss incurred when running the length of a 300-meter aircraft carrier.

APPLICATIONS OF RF-OVER-FIBER TECHNOLOGY

Defense Applications

RFoF technology has numerous applications in defense and homeland security. A common usage of the technology is in an ODL. ODLs combine RFoF technology with optical delay fiber segments. Progressive ODLs can introduce a range of delays by incorporating optically-switched fiber segments, typically arranged in an increasing order of delay. These instruments play an important role in testing and calibrating radar systems by introducing precise time delays to the RF signal to simulate target distances for surveillance and fire control radars. ODLs with fast delay switching can simulate range closing for proximity fuses or homing radars. Altimeter radars are calibrated and verified using ODLs that simulate heights above ground. ODL solutions are customized based on application requirements, supporting delays ranging from a nanosecond to milliseconds or from 0.5 to more than 100,000 ft. at virtually any desired step resolution. Additional features, such as high speed delay state switching, the number of delays, precision, accuracy, Doppler modulation, RF gain, bidirectional RF transmission and many more RF and optical features, may be added to meet specific application requirements. Both local and remote ODL control options are available. ***Figure 4*** shows an example of an RFOptic progressive ODL.

Phase-matched RFoF multichannel technology is essential for remoting direction-finding (DF) antenna arrays in defense applications. These arrays are used in radar and EW systems, which employ interferometry to determine the direction of targets. Phase-matched RFoF multilinks, stable over time and temperature, simplify DF algorithms and reduce the phase calibration overhead. Such systems can employ a four-antenna array for azimuthal location or an eight-antenna array, which adds elevation discrimination. A wider bandwidth of DF RF transmission corresponds to a higher spatial resolution of the target location. Furthermore, a wide DF RF bandwidth allows the use of frequency-dependent target reflections to identify a target. A militarized high frequency phase-matched RFoF system is shown in ***Figure 5***. It supports a DF link bandwidth of 1 MHz to 6 GHz and uses coarse wavelength division multiplexing optical multiplexing technology. It is designed for a four-antenna DF array system and includes ad-

Fig. 5 Six-channel miniaturized phase-matched militarized RFoF system.

ditional omnidirectional and calibration RFoF links. These additional links bring the total number of phase-matched channels to six. This RFoF DF solution features built-in step attenuators, which match the RFoF link gains across the four channels, thereby improving the system's performance. The RFoF links feature gain stability over a wide range of operating temperatures. Phase-matched RFoF technology achieves bandwidths up to 18 GHz with phase matching accuracy of ±10 degrees for a 1 km optical fiber cable length. Additionally, a 40 GHz phase-matched link with similar performance was demonstrated. These microwave and mmWave direct frequency solutions use wavelength division multiplexing technologies to ensure phase-matched performance. Both remote and local management capabilities are provided through an Ethernet-enabled management and control system or local USB connections.

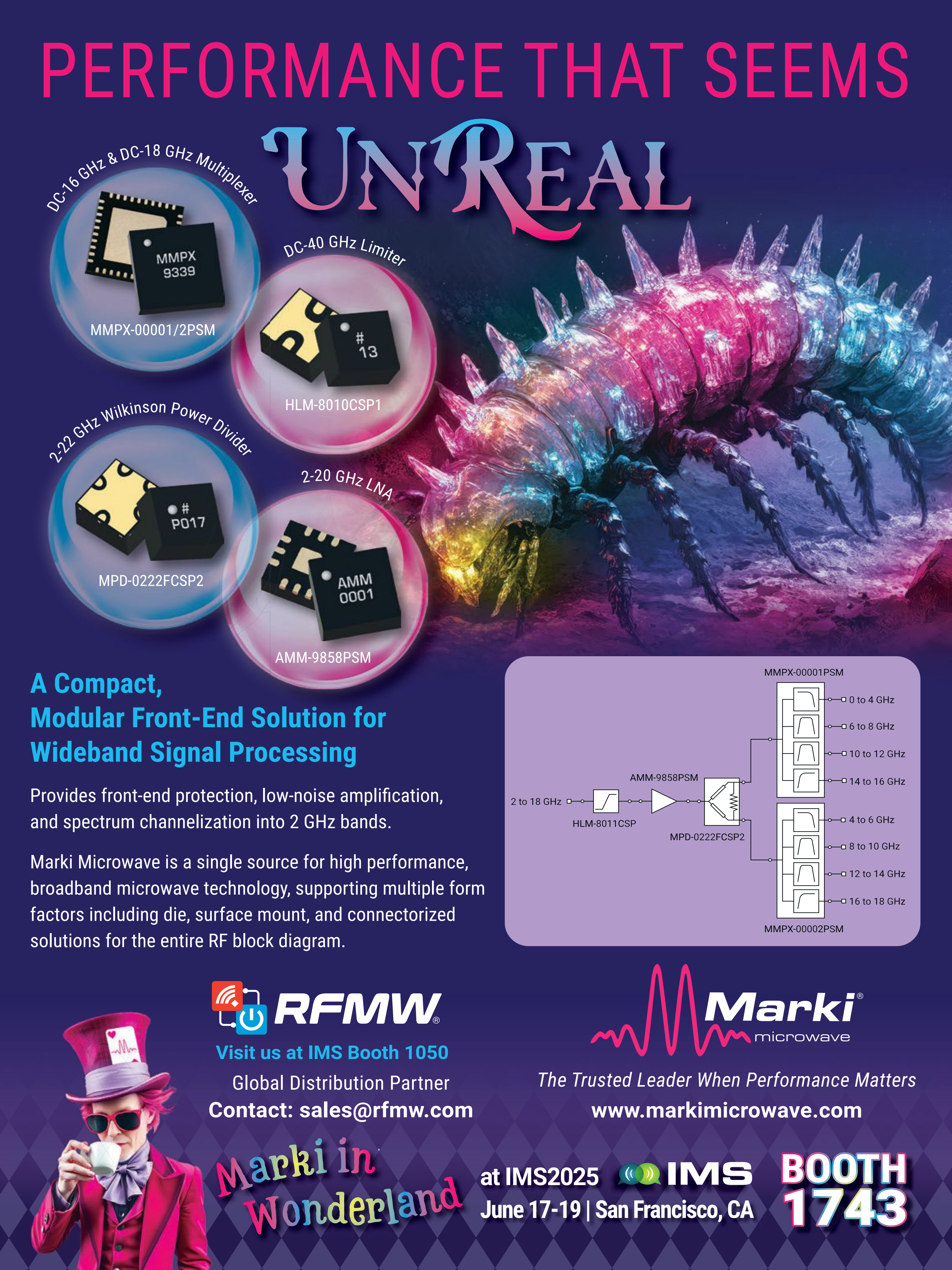
The RFoF technology may also be used in remote antenna ground stations for drones. With this technology, it is possible to use the concept of distance radiating. This concept enables the drone control trailers to be located separately from the drone control and telemetry antennas, which may be potential targets. This separation increases the survival rate of the control trailer and personnel while also enhancing communication reliability during drone operations. The system transmits flight control signals and receives real-time video and reconnaissance data across all compatible frequency bands. Optical switching can be applied to enable seamless handover between antenna locations, providing improved resiliency and redundancy.

RFoF technology can also create realistic product calibration, training and test conditions for evaluating radar systems. These target simulators use multiple emitters, either fixed or moving, along with sophisticated RFoF signal distribution and ODL segments to form a set of simulated maneuvering targets. The radar signal can be distorted or modulated to replicate real signals, radar cross section variations and EW jamming and spoofing techniques.

RFoF technology enables physical separation between expendable sensors or antennas and the sophisticated signal processing and aggregation equipment typically placed in a safe and shielded central location in remote sensing and surveillance applications. RFoF technology can provide coherent detection by distributing a common local oscillator to multiple sensor locations through optical means. Such surveillance systems are typically lightweight enough to be mounted in unmanned aerial vehicles and larger dedicated platforms, addressing airborne reconnaissance applications.

CIVIL APPLICATIONS

In the civilian sector, RFoF technology supports various critical applications.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RFoF technology is gradually replacing traditional RF switches and coaxial cables with optical switches and RFoF links in 5G testing and interoperability applications. This technology transition is driven by the demands of 5G and emerging 6G cellular and data communication technologies. The increasingly higher frequency communication bands, such as 5.8 GHz, cannot be effectively transmitted using coax cables and RF infrastructure. One area that has seen a fast adoption of RFoF technology is the 5G test environment, which focuses on validating the interoperability of base stations and mobile devices produced by different vendors. An array of base stations is connected to an optical switch using RFoF bidirectional terminals. From here, fibers lead to RFoF bidirectional terminals that service mobile devices and test equipment. The optical network is configured as needed for the test scenarios in a programmed sequence. The operational expenditure (OPEX) reduction of this reconfigurable test environment has a high utilization rate due to sharing test equipment. Additionally, the resources required to reconfigure the test setup between different tests drop to nearly zero. The entire test environment becomes programmatically reconfigurable using the RFoF subsystem's HTML/REST web server-based remote management system, which enables monitoring, verifi-

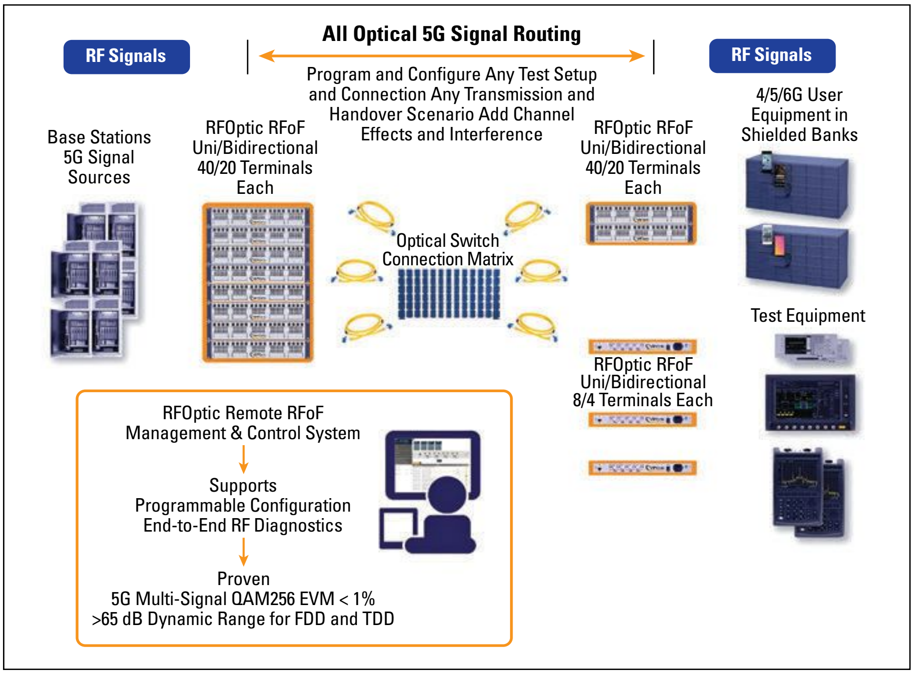

Fig. 6 Block diagram indicating RFoF applications in 5G testing.

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cation and control of individual channel performance. A block diagram of this scenario is shown in ***Figure 6***. ***Figure 7*** illustrates an example of a bidirectional RFoF terminal capable of accommodating 40 transmitters and receivers.

RFoF solutions provide reliable coverage extension in GNSS and Global Positioning System (GPS) applications. In these applications, GPS-over-fiber RFoF technology provides signals to shielded locations where direct satellite reception is blocked. These locations include parking garages, office buildings, tunnels, data centers and more. The RFoF GPS solution enables signal distribution and extension over long distances with minimal degradation, which is crucial for navigation and timing applications.

The technology also enables the extension of broadband communication capabilities into sheltered or shielded

Fig. 7 **High-density 2U enclosure.**

areas, utilizing DAS that can be employed in mines and buildings. Typically, in these cases, an area without reception is covered by antennas that carry a signal transported downstream by RFoF from a nearby location or rooftop with good reception. This location is referred to as the donor. In most cases, the DAS communication is bidirectional, requiring the aggregation of the upstream signals from all the antennas and their transport back to the donor. DAS solutions enhance the reliability and safety of mining operations by extending communication coverage throughout the mine or in similar sheltered areas, such as parking garages, office buildings and tunnels.

RFoF technology is crucial in radio telescope operations at observatories and other astronomy research endeavors. These systems facilitate the efficient transmission of wideband, high frequency RF signals over long distances, which is a critical requirement for applications such as very long baseline interferometry. Typical solutions provided to radio telescope centers include outdoor units with multiple RFoF transmitters that cover different frequency bands and are installed near the observatory dish antenna(s). These RFoF transmitters transport signals on bundles of optical fibers, ranging from 100 ft. to several thousand feet, to a corresponding set of receivers placed at the observatory control building. The RFoF links are designed for superior phase stability, allowing the processing of received signals into a high-resolution radio astronomical image of the observed target. RFoF enables seamless transport of wideband high frequency signals, which are essential for high-precision astronomical research.

PRACTICAL IMPLEMENTATION

Phase Matching for Radar Systems

RFOptic provided a phase-matched system comprising 10 channels in an outdoor enclosure, which included channels for communications. The system underwent approximately six

months of rigorous testing with parameters such as stability, signal quality and repeatability being meticulously measured. The RFoF system was qualified and deployed to transport signals in a DF application for border protection.

5G Network Rollout

RFOptic partnered with leading base station manufacturers to replace coaxial infrastructure with an optical fiber-based test system. The program's goal was to reduce the amount of test equipment, increase its utilization rate and decrease the setup and reconfiguration overhead. The implementation was successful, enabling the telecom company to enhance its capabilities for 5G interoperability testing, switch test plans from one test to the next in minutes instead of days and dramatically increase the test equipment use rate. The telecom company specifically required a solution that could address the limitations of existing RF switches and coaxial infrastructure, while also exceeding the error vector magnitude (EVM) and adjacent channel leakage ratio requirements of the 3GPP specifications for 5G cellular communication. The pilot deployment took place in the company's European laboratories to test base station equipment and validate interoperability. A bidirectional demonstrator RFoF system was provided for extensive testing and validation of the required performance. This RFOptic system, which was selected, accommodates up to 20 bidirectional links in five modular drawers and meets the company's performance, mechanical management and monitoring system requirements. This supports reduced OPEX and integration needs.

CONCLUSION

RFoF technology represents a substantial advancement in communication systems across both defense and civilian markets. Its myriad benefits include superior signal integrity, high bandwidth capacity, immunity to EMI and enhanced security. These and other benefits position the technology as an indispensable asset for contemporary wideband signal transport applications. From facilitating precise phase matching in defense systems to supporting the deployment of 5G networks, RFoF has demonstrated its utility in various critical scenarios.

As organizations increasingly adopt RFoF solutions, they will address current communication challenges and prepare for future advancements. As they enhance operational capabilities, these companies and this technology are paving the way for a more connected and efficient future with new and diverse applications. The defense sector is expecting increased demand for a wide range of applications, including ODL, along with multichannel phase-matched and phase-corrected transport and target simulators. Current applications that take advantage of the benefits of RFoF include remote antennas, remote ground stations, fiber-controlled drones, delayed signal processing, delayed repeaters, wideband DF and interferometry and true-time delay wideband phased arrays. New and previously unknown applications will undoubtedly emerge to leverage the RFoF technology and contribute to the growing list of existing applications already utilizing this technology. ■


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International Spectrum Supportability for Software-Defined Radios

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This is the first part of a two-part article on spectrum supportability for software-defined radios (SDRs). Part one serves as an introduction to U.S. federal systems using the new U.S. Department of the Navy (DON) Amphibious Tactical Communications Systems (ATCS) SDR as a surrogate for federal communication systems. The ATCS is currently being installed to provide a critical high-capacity terrestrial, ship-to-ship and ship-to-shore tactical radio relay communications system between expeditionary strike groups (ESG) afloat and U.S. Marine Corps (USMC) units ashore. The ATCS is a good example of multi-band multi-channel secure SDRs operating in congested and contested electromagnetic spectrum environments (EMEs).

Part two is a more technical discussion on the flexibility of SDRs opening the aperture. It will look beyond U.S. federal and Department of Defense (DOD) systems into commercial applications. It will focus on international spectrum supportability for SDRs and the need for these systems to operate internationally in countries with very different spectrum usage rights.

At their most basic level, SDRs are radio communications systems where the traditional hardware functions and elements (filtering, modulation and demodulation) are performed by software instead of hardwired components. This approach allows for greater flexibility by enabling the radio to adapt to different communications protocols, frequencies (within reason) and modulation types without significant hardware changes. A comparison of SDRs and traditional radios is shown in ***Figure 1***.

Spectrum supportability is a critical feature for a system to be used internationally. Spectrum supportability assesses whether the electromagnetic spectrum is available to support equipment operation or systems dependent on it. Completing a supportability assessment early in the design process will enable an SDR to operate in multiple countries that use different frequency tables. As part of the supportability assessment, SDR designers need to consider:

Spectrum Certification: The equipment must be certified by the appropriate agency.

Frequency Allocations: There are different tables of frequency allocations across the countries in the nations where the radio system will be used.

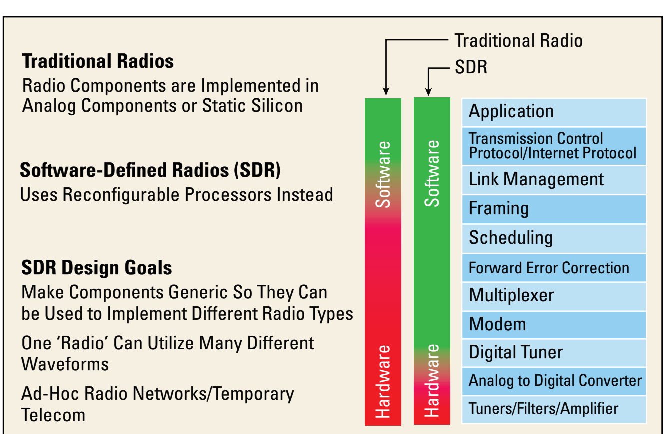

Fig. 1 Comparison of traditional radios with SDR systems.

Frequency Availability: Even though a specific frequency band has been allocated for radio system use, there also needs to be reasonable assurance that there are enough available frequencies for the system to operate.

Future Spectrum Planning: This typically includes spectrum harmonization[1] across countries, identification of new spectrum bands for future technologies, collaborative long-term planning, prioritizing specific spectrum allocations and facilitating spectrum sharing.

Electromagnetic Compatibility (EMC): The system needs to be able to operate acceptably in the presence of other electrical and electronic equipment and not adversely interfere with that other equipment.[2]

Both commercial and federal systems in the U.S. must go through spectrum supportability assessments before being certified for use. Looking at federal systems and using the U.S. Navy's (USN) ATCS SDR, which is currently being installed in the fleet, as an example system, this article will show that being able to operate globally is important both for the U.S. military and commercial systems and it can be accomplished through the use of system engineering at the beginning of the design process. Without doing a spectrum supportability assessment, bringing an SDR to an area where the frequency assignments do not support the capability of the equipment may get the same type of reception that Ilsa got when she walked into Rick's in the movie Casablanca: "Of all the gin joints in all the towns in all the world, she walks into mine." And that is to say, not a good reception. ***Figure 2*** shows an example of a USN amphibious ship.

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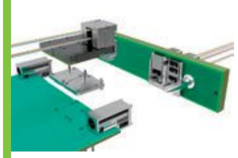

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WHAT IS ATCS

The mission and the problems that the ATCS SDR solves using spectrum supportability enable the DON to conduct global operations. The ATCS provides a critical, reliable, secure, high-capacity terrestrial, ship-to-ship and ship-to-shore voice, data and video tactical radio relay (TRR) communications system between the ESGs afloat and the USMC units ashore. Ship-to-shore communications have traditionally been more technically challenging than shore-to-shore radio relays because the ship is always moving. ATCS and its predecessor system overcame this challenge through a variety of technical methods to provide the initial communications link to forward-deployed Marines.

Fig. 2 USN amphibious ship. *Source:* Department of the Navy.

Fig. 3 ATCS rack. *Source:* Department of the Navy.

Spectrum supportability decisions are crucial for the DON, the DOD[3] and the other federal government agencies to ensure their systems and equipment can operate efficiently in their electromagnetic spectrum allocations. These supportability decisions combine operational needs with current spectrum availability and seek to minimize system interference. They ensure a system can run without breaching spectrum management policies or harmfully interfering with other spectrum users. To accomplish this complex assessment, numerous elements must be carefully analyzed. Spectrum supportability assessments also consider operational impacts, examining if spectrum constraints could impede system functionality and therefore mission completeness. In an unabashed reference to "The Princess Bride,"[4] a spectrum supportability assessment done right is like a nice mutton, lettuce and tomato sandwich, when the mutton is nice and lean and the tomato is ripe. Tactical systems like the ATCS are flexible with their spectrum access and need multi-band, multi-channel capabilities to operate in dynamic and congested spectrum settings. Coalition and multinational operations require systems to be interoperable with partner nations' technology and comply with international spectrum standards.

FIELDING SYSTEMS

ATCS is currently in the installation process. The plan is to install the system on 34 amphibious ships over the next several years. This will provide a sustainable and evolvable communications pathway for ship-to-ship and ship-to-shore line-of-sight communications, leading the DON capabilities into the future. ***Figure 3*** shows an ATCS rack.

The ATCS shipboard radio is a complete multi-channel, multi-band system of systems that enables a unified heterogeneous wireless network (HETNET) capable of supporting different types of users in contested and congested electromagnetic spectrum (EMS) environments. A HETNET can be several different things depending on the context. In this instance, it is a wireless network with different access technologies.[5]

Spectrum supportability decisions align with domestic and international laws. Federal systems, including the Navy's ATCS SDR, must follow the National Telecommunications and Information Administration (NTIA) Manual of Regulations and Procedures for Federal Radio Frequency Management.[6] International systems must also follow the International Telecommunications Union (ITU) spectrum standards. These regulations ensure that systems are certified for their spectrum bands and that any conflicts are discovered and resolved during design. The DOD recognizes that the EMS, like fresh water,

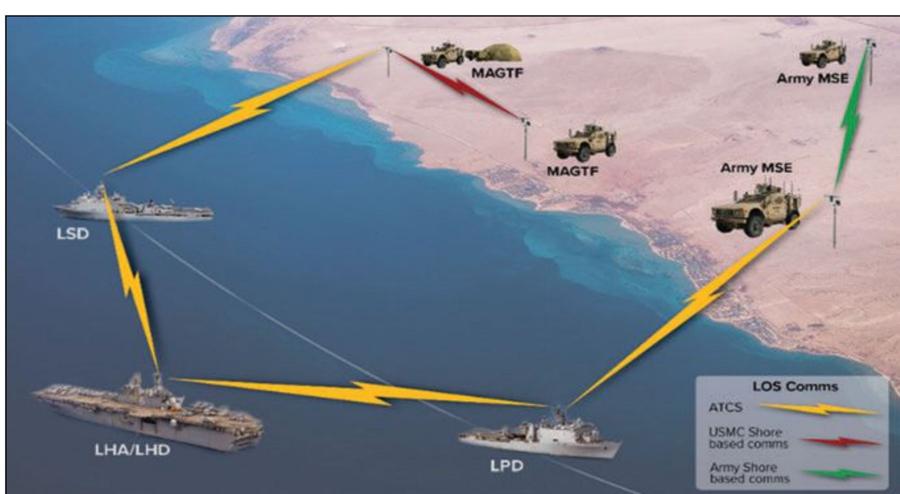

Fig. 4 Operational concept for ATCS integration into Army and USMC-compatible communication systems. *Source:* U.S. Navy.


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is a precious commodity and a maneuver space essential to all warfighting domains: land, air, sea, space and cyber. To effectively operate for humanitarian missions and on the battlefield, all participants need access to the EMS. Operating across multiple frequency bands increases the effectiveness of the system and the warfighter. The ATCS multi-band capability provides the DON with secure communications in environments where satcom capabilities are limited or nonexistent. As in the civilian sector, the federal government recognizes that the same is true; the backbone of American society runs on the EMS: science, communications, commerce and emergency services.

Figure 4 shows how ATCS can be integrated into ground-based U.S. Army- and shore-based USMC-compatible communication systems. The USN to USMC ship-to-shore communications capability has been a requirement for the DON since the mid-1990s. As warfare requirements and technology have evolved, this requirement has remained an absolute necessity. As shown in Figure 4, communication between the USN and the USMC is critical because they operate as a combined force, requiring seamless information sharing to execute complex and dangerous missions effectively. This is especially true during amphibious operations where the USMC rely on landing vessels for transport and fire support, necessitating reliable communications for coordinating movements and decisions during humanitarian and battlefield operations.

The ATCS radio was developed and produced by Ultra Electronics, who also make the Orion X500 software-defined tactical radio system used by the USMC for line-of-sight communications. The Orion radio platform is already in use across the DOD. This procurement ensures that the DON has interoperability with the U.S. Army and U.S. Special Forces, who already use the system. It is replacing a traditional, inflexible, hardware-based radio system developed and deployed during the 1990s. The Orion radio is also currently used by the Canadian Department of National Defence and the U.K.'s Ministry of Defense in addition to the U.S military. This broad usage enables coalition operations.

THE IMPORTANCE OF SDRS

Just as amphibious warfare is critical to the offensive posture of the modern naval force, reliable and secure communications are crucial to successful amphibious operations. SDRs enable TRRs, which are crucial to the mission of the modern military. TRRs are secure and efficient point-to-point communication networks allowing military forces to communicate across the world's diverse terrains without wires. Using multiple systems in a relay builds in redundancy, ensuring reliability. By hopping transmissions across shorter distances, the military forces can achieve their objectives with lighter-weight, more portable equipment. ***Figure 5*** shows a stock photo of forces from the USMC executing a simulated amphibious assault.

The ship-to-shore communications portion of ATCS is critical to the DOD and naval forces. It enables critical information to be exchanged between ships and land-based command centers. This enables operations coordination and overall situational awareness, bringing together the naval forces' land and sea-based portions.


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In the USMC and the U.S. Army, the Orion family of systems is replacing older systems that have been in use since the early 2000s. These systems have provided a ship-to-shore and shore-to-shore TRR capability to forward positions such as operating bases, checkpoints, command posts and other widely dispersed units across Haiti,[7] Iraq and Afghanistan. As seen in these areas, the units involved in counterinsurgency and humanitarian missions are scattered across wide areas with minimal reach-back support. This makes reliable communications essential to mission success. ***Figure 6*** shows Marines setting up an MRC-142 radio antenna for line-of-sight, point-to-point radio communications.

COALITIONS

The success of contemporary military operations is contingent upon establishing secure and sustainable communications in congested and contested electromagnetic environments. Currently, militaries worldwide seldom operate in isolation; instead, they collaborate as members of coalitions. In addition to facilitating the exchange of knowledge, innovative practices and technologies across cultural and physical borders, this coalition-based approach also enhances combat effectiveness by capitalizing on the collective strengths of allied nations. This interoperability is essential in dynamic operational environments, promoting

Fig. 5 U.S. Marines executing a simulated amphibious assault. *Source:* U.S. Marine Corps.

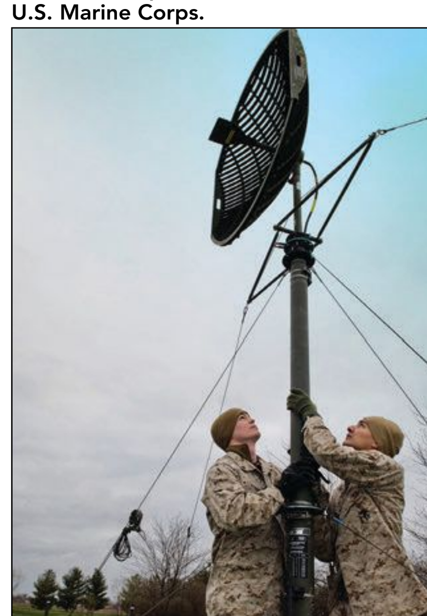


Fig. 6 Marines setting up MRC-142 radio antenna. *Source:* U.S. Air Force.

adaptability and agility.

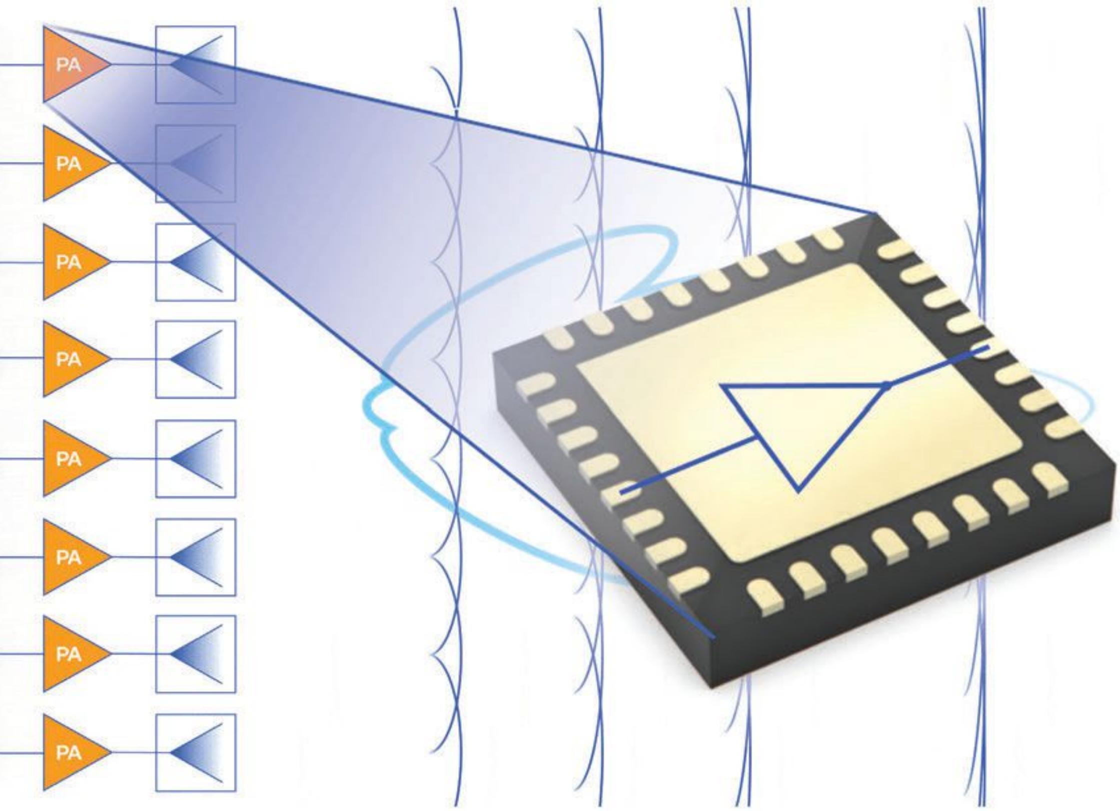
Similarly, commercial communication systems are no longer restricted to specific nations or regions. For these systems to continue to be commercially viable, they must be able to support global operations across multiple countries, each with its own regulatory frameworks and spectrum allocations. This global approach to design and deployment guarantees that systems can function seamlessly in a variety of environments while simultaneously addressing obstacles such as varying levels of technological infrastructure, frequency allocations and spectrum usage rights. It is essential to harmonize and integrate these diverse requirements to guarantee SDRs are universally functional, scalable and reliable, regardless of whether they are used in military or commercial settings.

CONCLUSION

SDRs represent a transformative advancement in global communications, offering the flexibility to adapt to diverse operational environments. The ability of SDRs to operate across multiple bands, modulation schemes and protocols highlights their versatility, especially in congested and contested electromagnetic spectrum environments. Spectrum supportability is a cornerstone of SDR deployment, ensuring these systems comply with domestic and international regulations, operate without interference and meet mission-critical demands. The integration of spectrum harmonization across countries further amplifies the utility of SDRs, enabling seamless operation in coalition and multinational environments. SDR flexibility, robust spectrum supportability processes and global spectrum harmonization pave the way for reliable, secure and interoperable communications, enhancing military and commercial operations in an increasingly interconnected world. ■

REFERENCES

1. Digital World, "Managing Growth, Managing Spectrum: Best Practices in Spectrum Harmonization," *ITU Telecom World*, September 21, 2021, Web: https://digital-world.itu.int/managing-growth-managing-spectrum-best-practices-in-spectrum-harmonization/.
2. P. R. Clayton, *Introduction to Electromagnetic Compatibility*, 2nd Edition, Wiley-Interscience, 2006.
3. Chief Information Officer (DOD CIO), *Policy and Procedures for Management and Use of the Electromagnetic Spectrum*, Washington, District of Columbia: Department of Defense, January 9, 2009, Incorporating Change 1, October 17, 2017.
4. R. Reiner, director, "The Princess Bride," Twentieth Century Fox, 1987.
5. R. Akeela and B. Dezfouli, "Software-defined Radios: Architecture, State-of-the-Art, and Challenges," *Computer Communications*, Vol. 128, 2018, pp. 106–125.
6. National Telecommunications and Information Administration (NTIA), "Manual of Regulations and Procedures for Federal Radio Frequency Management," *District of Columbia: Department of Commerce*, 2021, Revised January 2023.
7. Defense Media Activity Anacostia, "UPDATE: U.S. Navy delivers assistance, capabilities to unified response in Haiti," Militarynews.com, January 10, 2010, Web: https://www.militarynews.com/norfolk-navy-flagship/news/top_stories/update-u-s-navy-delivers-assistance-capabilities-to-unified-response-in-haiti/article_26b401c0-a768-582f-ad1e-237ad35c24e2.html.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Quick Triage Strategy for Troubleshooting AESA TR Modules and Test Stations

John Vincent Hart III
Northrop Grumman Aeronautics Systems, Palmdale, Calif.

High production throughput is required in RF test facilities to meet transmit-receive (TR) module delivery schedules. Unfortunately, unexpected failures occur and determining whether the TR module, the test station, the fixture or the cables are at fault is challenging for technicians and engineers to ascertain promptly. Additionally, management is understandably impatient, trying to contain schedule creep, costs and any potential reputation damage resulting from late deliveries. Typically, the primary test failure concern relates to the design of the TR module and initial test failure investigations focus on any inherent design flaws in the TR module. These investigations must also consider whether there are more significant production and/or manufacturing producibility issues. If there are, these findings may then dovetail into concerns about personnel training, material or process planning instructions. The need to quickly isolate the failure and discover its root cause creates a crucial organizational challenge.

This type of problem necessitates a quick triage solution. This article will describe a process that uses fundamental physics of failure troubleshooting methods with Smith charts, polar charts, network analyzers and deriving and applying NASA-developed troubleshooting techniques. Using these techniques, the article will demonstrate how to quickly and qualitatively determine whether the issue lies with the module or the test station and identify the failure mechanism.[1] In the examples that will be used, the enemy of the analysis was determined to be time. The goal was to develop a method that avoids lengthy, drawn-out quantitative analysis, which typically involves RF plotting and potentially, multiple retests of TR modules to determine the condition of a suspect TR module. While this legacy approach is sound, it often yields ambiguous and time-consuming results. The technique that has been developed has the triage goals of enabling the failure to be identified qualitatively, quickly and intuitively. The article will present two evidentiary examples to illustrate this method.

LITERATURE REVIEW

Earlier Research

To develop faster methods of troubleshooting, a NASA-authored paper[1] offers intriguing insights. This paper incorporates an analog component current versus voltage curve tracing method. In addition, it includes a method of troubleshooting through complex impedance characterization of RF transitions, utilizing polar plots or Smith charts.[2] Complex impedance characterizations made with Smith charts and polar plots of a golden, known-good and a suspect transition reveal qualitative differences; at interest is the qualitative content.

Findings and Unanswered Questions

In most test environments, programmable network analyzers (PNAs) do not employ Smith chart plots in the test sequence. At this point, it is worth noting that a PNA can directly plot a Smith chart or one can be post-processed in MATLAB using a .s2p Touchstone file.[3] Typically, test environments limit RF PNA plots to two-port S-parameters of an AESA TR module. These are S_{11} and S_{22} (input and output return loss), S_{12} and S_{21} (reverse and forward transmission). Although pejorative artifacts can be found in suspect cables by S-parameter analysis, using this method is not as quick, does not contain as much information and is typically more cumbersome than other methods of reactance artifact discovery.

The S_{12} term relates to insertion loss, which is directly related to the cable's internal center conductor. The S_{11} term relates to the input impedance or the relationship between the center conductor and the cable's metallized outer shield. The S-parameter definitions for a two-port network are shown in ***Figure 1***.

Where:

$S_{11} = b_1/a_1$ = forward reflection coefficient

$S_{12} = b_1/a_2$ = reverse transmission coefficient

$S_{21} = b_2/a_1$ = forward transmission coefficient

$S_{22} = b_2/a_2$ = reverse reflection coefficient

Return loss is related to the reflection coefficient, Γ, and the VSWR as shown in ***Table 1***.[4]

PRELIMINARY S-PARAMETER AND SMITH CHART WORK

The observation of minor reactance artifacts during slight flexion of the RF cable prompted this investigation. This bending resulted in an instability that

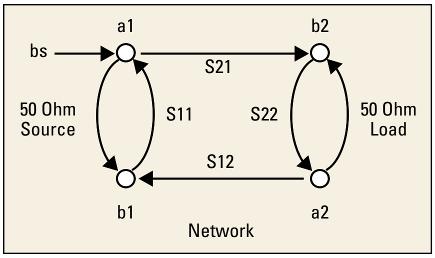

Fig. 1 S-parameter definitions for a two-port network.

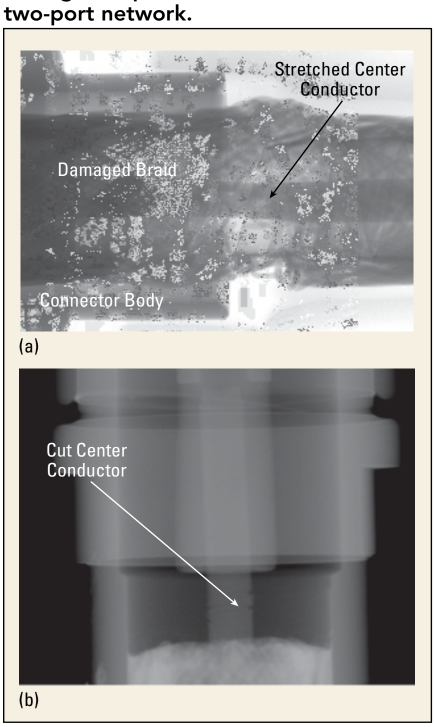

Fig. 2 (a) Radiograph of damaged braid and stretched conductor. (b) Radiograph showing Teflon and center conductor cut.

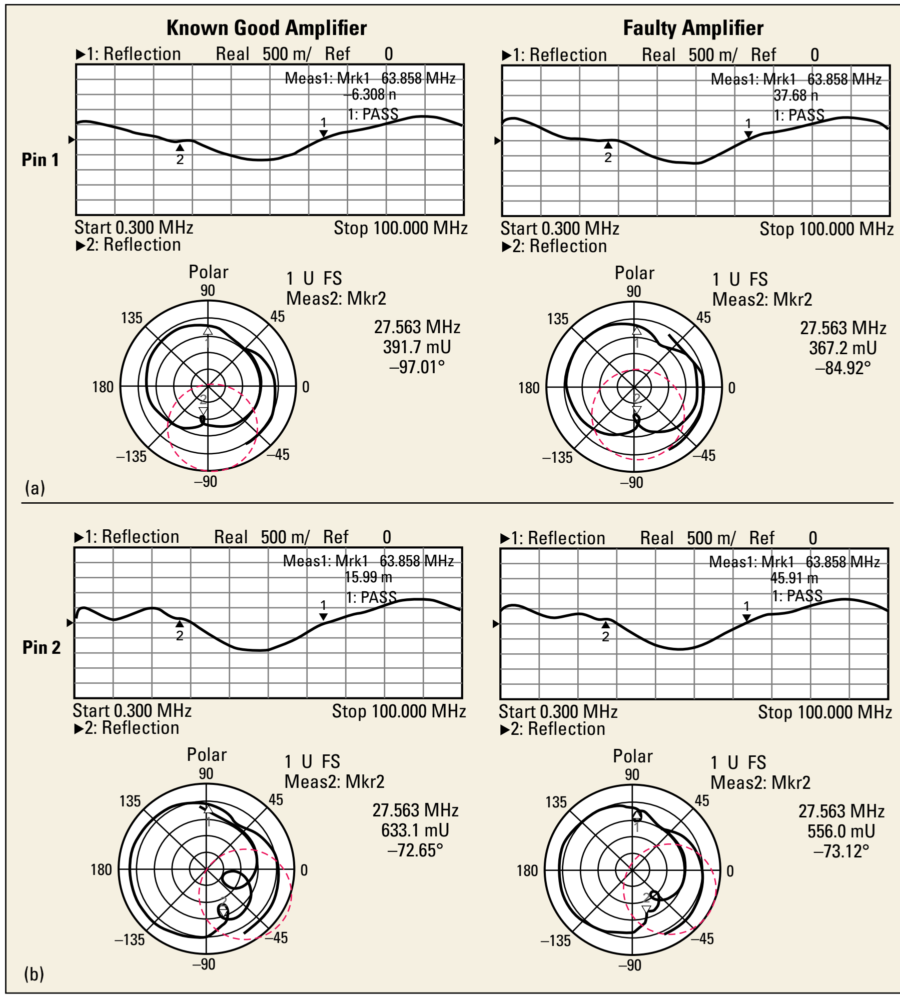

Fig. 3 (a) Cartesian and polar plot reflection response at amplifier Pin 1. (b) Cartesian and polar plot reflection response at amplifier Pin 2.

manifested in the S_{11} plots. A visit to the RF cable manufacturer, along with electrical results and radiographs, confirmed that a technician used a scalpel to remove the outer cable jacket, inadvertently penetrating the outer cable shield and cutting the polytetrafluoroethylene (PTFE) dielectric that surrounds the center conductor. At higher frequencies, skin effect dominates and the signal will concentrate near the surface of a conductor. Any tears in the outer metallized braid can cause unwanted reflections that will degrade the reflection coefficient presented to the incoming signal.[5] ***Figure 2a*** shows a radiograph of the damaged braid and stretched center conductor resulting from the inadvertent penetration of the outer braid and cutting of the Teflon™ (PTFE). ***Figure 2b*** shows the cut to the PTFE dielectric around the center conductor. The ideal method for removing the outer jacket involves an intentionally dull thermal stripper. With gentle pressure, there is no damage to the metallized braid or the underlying layer of PTFE dielectric.

Since S_{11} is most closely linked to return loss and VSWR, it is the most likely indicator of a cable assembly issue. S_{22} measures the reverse reflection coefficient and this measurement also showed perturbation artifacts. There was evidence of reactance effects in the S_{12} and S_{21} results with minor ripple indications in the signal content, but these ripples were on the order of tenths of a dB.[5]

TABLE 1

RETURN LOSS AND VSWR RELATIONSHIPS

Return Loss	Voltage Standing Wave Radio	Reflection Coefficient
$Return\ Loss = -20 \cdot \log_{10}\left(\frac{VSWR-1}{VSWR+1}\right)[dB]$ $ReturnLoss = -20 \cdot \log_{10}\lvert\Gamma\rvert[dB]$	$VSWR = \frac{10^{\frac{ReturnLoss(dB)}{20}}+1}{10^{\frac{ReturnLoss(dB)}{20}}-1}[:1]$ $VSWR = \frac{1+[\Gamma]}{1-[\Gamma]}[:1]$	$\lvert\Gamma\rvert = 10^{\frac{-ReturnLoss(dB)}{20}}$ $\lvert\Gamma\rvert = \left\lvert\frac{VSWR-1}{VSWR+1}\right\rvert$

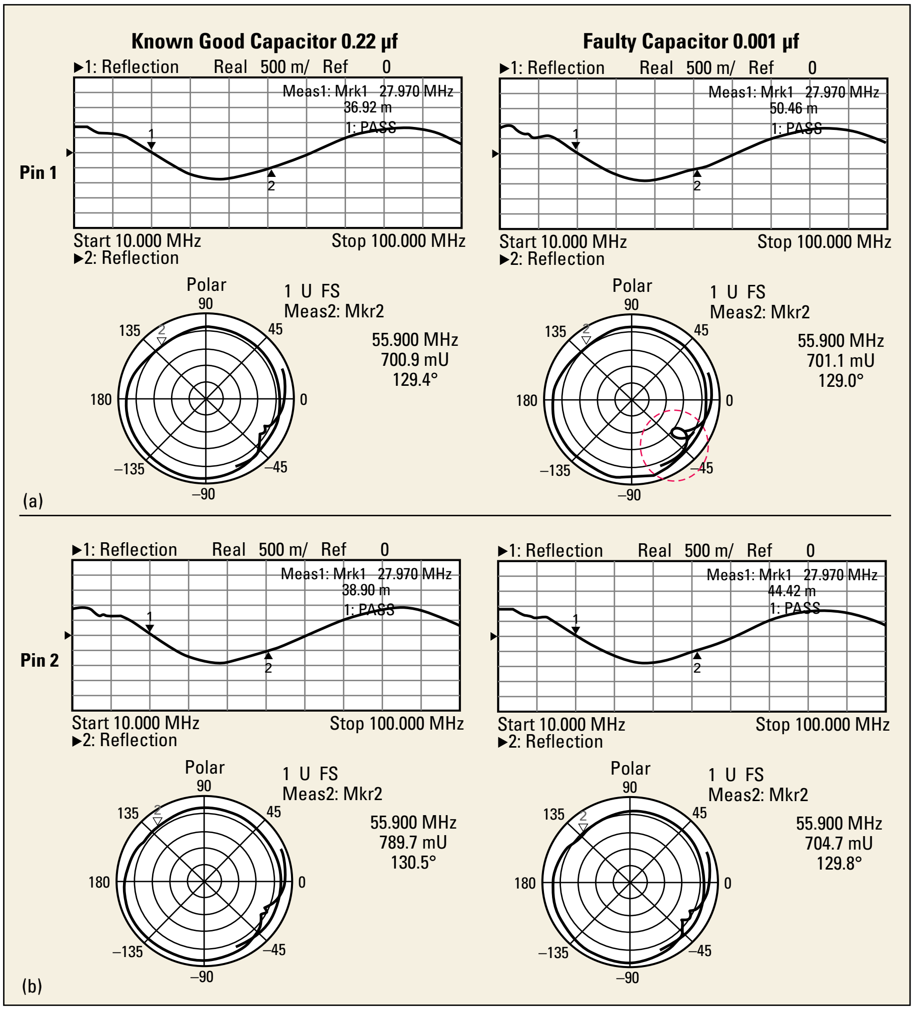

Fig. 4 (a) Cartesian and polar plot response at capacitor Pin 1. (b) Cartesian and polar plot response at capacitor Pin 2.

METHODOLOGY

Methodology and Analysis

Although cable issues were detected and identified, this process was time-consuming. A quicker way to determine the problem would have been to use complex impedances, polar plots or Smith charts. ***Figure 3a*** shows reflection plots measured at Pin 1 of a known-good amplifier compared to a faulty amplifier. Below the Cartesian plots are polar plots of the same measurements. The Cartesian plots show little difference between the two amplifiers, but the complex impedance characteristics in the polar charts show a frequency shift and a more discernible difference in the response. ***Figure 3b*** shows the same analysis at Pin 2 of the amplifiers.[1,7]

Figure 4a shows the same analysis for a good versus a faulty capacitor. While the Cartesian plot shows a slight difference at lower frequencies, the difference in the trace characteristics on the polar plot is more noticeable. ***Figure 4b*** shows this same analysis at Pin 2 and even using the polar plots, the change is very subtle.[1,6]

The thesis for the NASA paper[1] is that analysis is faster using polar plots than Smith charts. They attribute this to the Smith chart's complexity. While this belief holds some truth, many of the Smith chart complexities can be overcome with some explanation. ***Figure 5*** shows a simplified Smith chart with the pertinent regions and formulas identified for reference.[2]

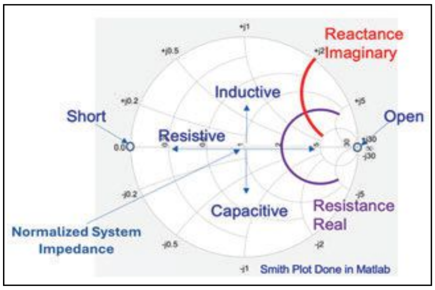

Fig. 5 Simplified Smith chart.[2]

SMITH CHART FUNDAMENTALS

The center of the Smith chart is normalized to the characteristic impedance of the system. In the case of most RF systems, this is 50 Ω.[8] All the points on the Smith chart are complex impedances that are represented by a real and imaginary part given by ***Equation 1***:

$$Z = R + jX \tag{1}$$

Where:
Z = complex impedance
R = real or resistive component, which is independent of frequency
X = imaginary or reactive component
j = imaginary unit of √-1

X, the reactive portion of the complex impedance, is frequency dependent and can be described by ***Equation 2***:

$$X = X_L + X_C \tag{2}$$

Where:
X_L = inductor impedance = 2πFL
X_C = capacitor impedance = 1/2πFC

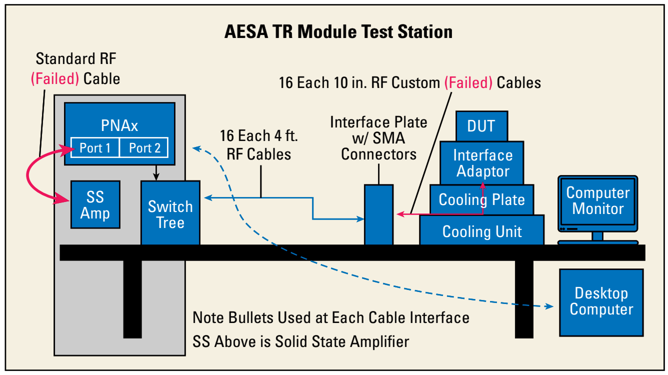

Fig. 6 Automated test stand block diagram.

F = Frequency (Hz)
L = inductance (Henries)
C = capacitance (Farads)

With that brief refresher, the Smith chart is a valuable analysis tool. It is helpful because it incorporates the effects of the total impedance in the system analysis. This is especially true of the reactive properties and will become clearer in the results section of this article.

VALIDATION EXAMPLES

Test Setup

The rest of this article presents the measurement and validation method using two examples. Two different test setups were used to evaluate the known-good TR module. The first setup used cables that were less than 1.5 ft. long and suspected of being faulty; they interfaced between the PNA and TR module. One PNA port was connected to the TR module input, with the output connected to the second PNA port.

The second test setup, shown functionally in ***Figure 6***, measured the same known-good TR module with a significantly more complex configuration using an automated test station. The test station of Figure 6 uses approximately 4 ft. of cable with two more transitional connection points than the lab design validation testing setup described earlier. This test station contains a switch tree, a box containing multiple electrically actuated RF switches and an interface panel that connects short, smaller-diameter RF cables to longer, larger-diameter RF cables. These longer, larger-diameter cables transition to the faulty RF cables.

Since the goal is to ensure measurement validation with network analyzer calibration, it is important to use best practices. This means using calibrated torque wrenches, proper connector collar rotation procedures and an electronic calibration (ECAL) standard. There are many calibration standards. However, the ECAL standard, with a set of five internal reference impedances, enables sufficient testing speed and accuracy for baseline reference accuracy.[9] A known-good reference cable was used to ensure measurement accuracy, stability and repeatability.

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DATA RESULTS

Plotting the PNA Data

1. Capture the data or load it onto the PNA-X as shown in ***Figure 7***
2. Hover over the trace to be displayed on a Smith chart. This is the S_{11} trace in Figure 7

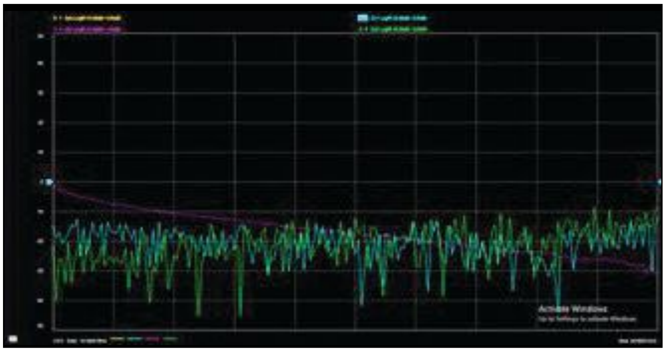

Fig. 7 PNA-X data display.

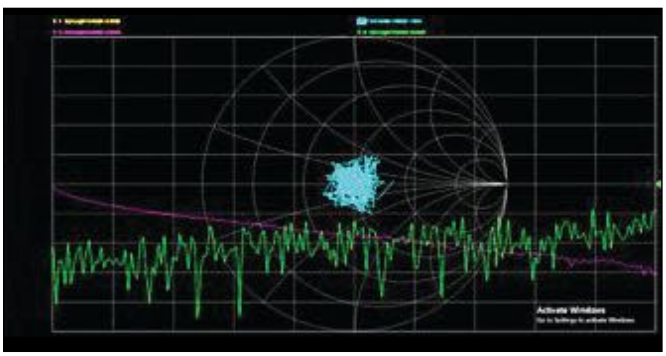

Fig. 8 Smith chart data overlay.

Phased Array System Toolbox	Version 4.1	(R2019a)
RF Blockset	Version 7.2	(R2019a)
RF Toolbox	Version 3.6	(R2019a)
Robust Control Toolbox	Version 6.6	(R2019a)

Fig. 9 Display of MATLAB packages.

3. Right-click the trace identifier and scroll to "Format/Smith chart"
4. Left click "Smith chart"
5. This overlays the S_{11} trace onto a Smith chart as shown in ***Figure 8***.

Smith Chart Plot With MATLAB

1. Type "ver" in the command line of MATLAB and verify that RF Toolbox is installed, as shown in ***Figure 9***
2. Create a new MATLAB project folder as shown in ***Figure 10***
3. Load the .s2p files to analyze into this folder
4. Create a new MATLAB script using the code shown in ***Figure 11***.

Running this script should return a plot like ***Figure 12***. To magnify the display in MATLAB, click the center of the plot and scroll the mouse wheel while holding the Ctrl key.

Polar Plot Chart Using MATLAB

1. Verify that RF Toolbox is installed as before and load the desired .s2p files into an existing or newly created MATLAB project folder
2. Create the MATLAB script shown in ***Figure 13***.

Running this script should return a plot like that shown in ***Figure 14***.

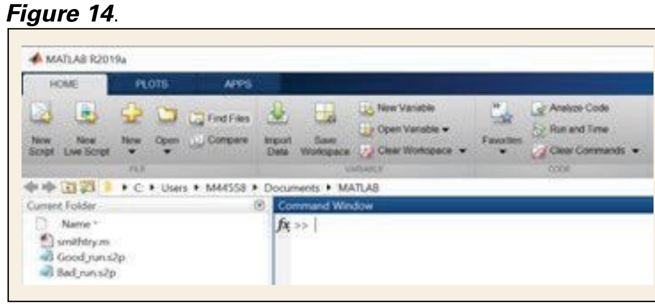

Fig. 10 MATLAB environment.

```
Editor - C:\Users\M44558\Documents\MATLAB\smithtry.m
smithtry.m
data = sparameters('Bad_run.s2p' ); %Load your s2p data into matlab format
s = sparameters(data,50); %Ensure that your reference impedance is at 50 Ohms
ports = [1,1;2,1;2,2]; %Express which Sparameters you would like to plot
p = smithplot(s, ports, 'GridType','ZY') %Plot the smith of input data
```

Fig. 11 MATLAB code.

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ANALYSIS OF RESULTS

Example 1

The first example of these methods uses both test setups described earlier to measure the TR module. The simplified test setup uses directly connected cables with as few adaptors as possible. The more complex test setup incorporates several switch paths, more adapters and longer RF cables to the TR module. ***Figure 15*** shows the data from both test setups plotted on a Smith chart. The data from the simplified test setup, on the left, is smooth and a bit more tightly grouped around the center of the Smith chart. The data from the automated test setup on the right shows more ripple and curling, indicative of reactive oscillations and resonances.

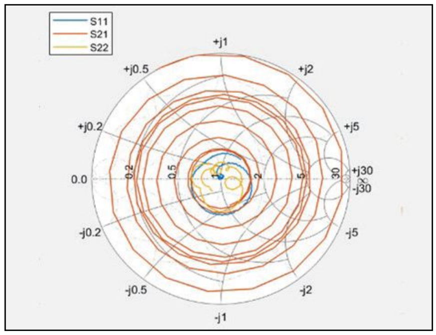

Fig. 12 Smith chart data display.

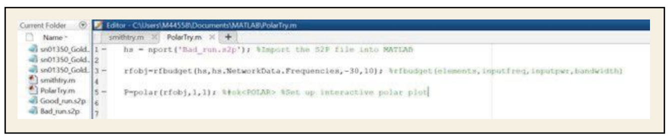

Fig. 13 MATLAB polar chart script.

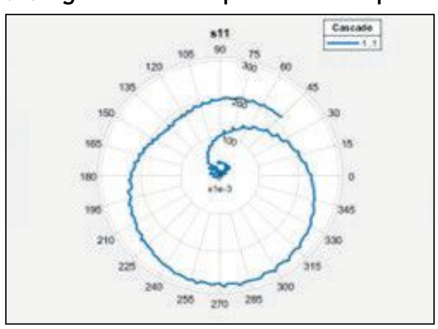

Fig. 14 Polar chart of results.

Example 2

RF compression failures became an ongoing issue in actual TR module production testing. The result was that approximately 80 TR modules failed to meet the 1 dB compression requirements and were awaiting rework to replace the RFIC amplifiers. The alternative solution was determining if a test station issue was the root cause of the failures. Compounding the issue, the known-good module had been tested with a bad cable. Once modules that had previously tested good began returning for retest, evidence began pointing to the automated test station as the source of the problem.

With evidence pointing to a faulty test stand, the question became, were the module test fixtures, cables or switches to blame? ***Figure 16*** shows the S-parameter measurements for the known-good and suspect cables. While the circled areas in ***Figure 17*** show some differences, the changes in magnitude do not clearly indicate a failure.

However, the fault becomes readily apparent when the data is plotted on a Smith chart, as shown in Figure 17. The plots in Figure 16 did not indicate the reactance and oscillatory behav-

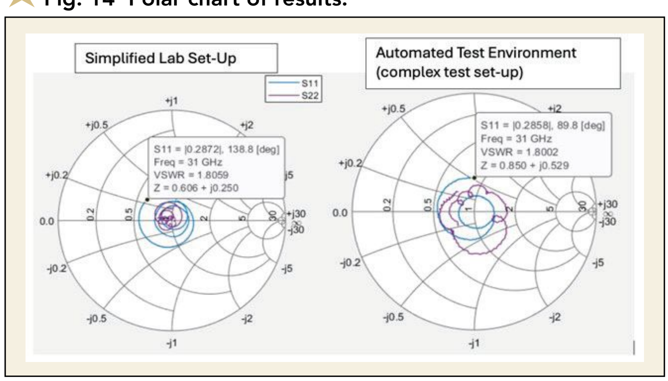

Fig. 15 S_{11} data using the simplified (left) and automated (right) test setups.

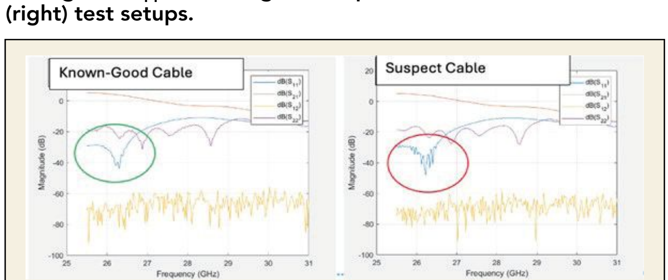

Fig. 16 S-parameter plots.

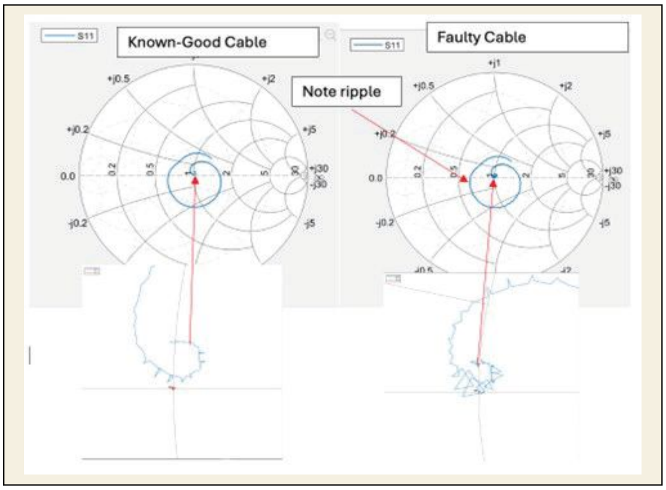

Fig. 17 Smith chart plots for a known-good (left) and a faulty (right) cable.

ior shown in Figure 17. This oscillatory behavior presents as the triangular patterns that appear when the area around the center of the Smith chart is blown up for the faulty cable data shown on the right side of Figure 17. In the expanded portion of the curve, the triangular traces move from the capacitive region below the R = 0 horizontal axis to the inductive region above the R = 0 axis, which shows a resonance at these frequency points.

CONCLUSION

This effort was motivated by the need to develop a fast and efficient way to analyze and validate test stations and procedures used to measure production quantities of TR modules. This article presents a quick triage method of analyzing measurement data by plotting it on a Smith chart. With AI and machine learning (ML) techniques becoming increasingly prevalent, the attractiveness of using techniques like these to locate device failures quickly will increase. Tools like a trained MATLAB/Python ML/AI algorithm script could compare measured to saved Smith chart data.

While this is feasible, issues remain with programmability. Techniques must be developed to determine and size the appropriate boundaries to maximize the ability to find true failures and minimize the likelihood that good units are incorrectly identified as failures. Testing yields and production module throughput will increase when reasonable solutions are found for these challenges. This will positively impact rework costs and manufacturing timelines, making the business case for these activities even more attractive. ■

References

1. R. Oeftering, P. Wade and A. Izadnegahdar, "Component-Level Electronic-Assembly Repair (CLEAR) Spacecraft Circuit Diagnostics by Analog and Complex Signature Analysis," NASA/TM-2011-21-216952, CLEAR–RPT–003, *NASA*, January 2011.
2. K. Blattenberger, (n.d.), "Impedance and Admittance Formulas for RLC Combinations," *RF CAFE*, rfcafe.com/references/electrical/impedance-admittance-formulas-rlc.htm.
3. "rfplot.plot S-parameter data," *Mathworks*, MATLAB, 2024, mathworks.com/help/rf/ref/rfplot.html.
4. K. Blattenberger, (n.d.), "VSWR-Return Loss- Γ Conversions," *RF CAFE*, rfcafe.com/references/electrical/vswr.htm.
5. K. Blattenberger, (n.d.), "Skin Depth (a.k.a. Skin Effect) as a function of Frequency, Permeability, & Conductivity," *RF CAFE*, rfcafe.com/references/electrical/skin-depth.htm.
6. K. Blattenberger and J. L. Cahak, (n.d.), "Computing with Scattering Parameters," *RF CAFE*, rfcafe.com/references/articles/Joe-Cahak/Computing-Scattering-Parameters.htm.
7. "Impedance Matching and Smith Chart Impedance" *Analog Devices*, July 2022, analog.com/en/resources/technical-articles/impedance-matching-and-smith-chart-impedance-maxim-integrated.html.
8. S. Bramble, "Radio Frequency (RF) Impedance Matching: Calculations and Simulations," *Analog Devices*, October 2021, analog.com/en/resources/technical-articles/radio-frequency-impedance-matching-calculations-and-simulations.html.
9. "Using ECAL," (n.d.), *Keysight*, helpfiles.keysight.com/csg/N52xxA/S3_Cals/Using_ECal.htm.

FOR FURTHER READING

1. "Automatic Fixture Removal (AFR)," (n.d.), *Keysight*, helpfiles.keysight.com/csg/e5080b/S3_Cals/Auto_Fixture_Removal.htm.
2. E. Pedrosa, "The Relevance of Phase Stability over Temperature in Microwave Cables, "Huber+Suhner, *EverythingRF*, August 2019, everythingrf.com/community/the-relevance-of-phase-stability-over-temperature-in-microwave-cables.
3. Chaniotakis and Cory, "Frequency Response: Resonance, Bandwidth, Q factor," *MIT*, 2006, ocw.mit.edu/courses/6-071j-introduction-to-electronics-signals-and-measurement-spring-2006/5bcec4bfba5f2e99754b77509e9e7ab4_resonance_qfactr.pdf.
4. "Pulsed Measurements Using Narrowband Detection and a Standard PNA Series Network Analyzer," *Keysight*, January 2017, keysight.com/us/en/assets/7018-01160/application-notes/5988-9480.pdf.
5. "smithplot. plot measurement data on a Smith Chart," *Mathworks*, MATLAB, 2024, mathworks.com/help/rf/ref/smithplot.html.

Liquid-Cooled SSPA for Satcom Uplinks

Empower RF Systems
Los Angeles, Calif.

Engineered for demanding satcom uplink applications, the Empower RF Model 2253 solid-state power amplifier (SSPA), shown in ***Figure 1***, combines solid-state technology with a modular, liquid-cooled architecture. Operating from 1750 to 2120 MHz, the 2253 provides a 7 kW peak and 3.5 kW RMS of digitally-modulated output power. The 2253 is the latest member of Empower's standard liquid-cooled SSPAs built for critical applications requiring solid-state power and high availability. The 2253 system comprises a 6 ft. rack, eight 2U amplifier drawers, a built-in cooling distribution unit (CDU) and an external heat exchanger.

The architecture of the 2253 is distributed and modular, the latter allowing field replacement of amplifier drawers, the controller and CDU, as shown in ***Figure 2***. The distributed RF and power supply design eliminates single points of RF failure, delivering "always on air" operation and minimizing downtime. The distributed system design provides system redundancies, allowing continuous amplifier operation at maximum potential in the event of partial failures. Similar to N+1 configuration redundancy, the 2253 offers impressive effective mean time between failures.

The 2U amplifier drawer forms the essential foundation that enables the transmitter's superior availability. Each 2U chassis is a fully functioning, integrated amplifier with full gain and no external driver or external system power supply needed at the rack level. The phase and gain of the 2U amplifier are set digitally. The rear panel consists of blind-mate electrical and dripless liquid connectors, ensuring the unit is field serviceable.

The system controller for the transmitter incorporates a high speed embedded computing architecture to ensure control, monitoring and protection of the individual 2U amplifier drawers. The system controller is common across Empower's liquid-cooled family and can manage a single or scaled version of the 2253 system. When scaled up, one or more additional racks are added in parallel for higher power; however, the system controller manages the combinations as a single entity.

The amplifier system includes a range of features designed to enhance performance, reliability and ease of integration. The system offers instrument-grade measurement capabili-

Fig. 1 Empower RF Model 2253.

Fig. 2 The back and front panels of the CDU.

TABLE 1 SUMMARY OF SYSTEM BENEFITS

User Benefits	Description	Operational Impact
Reliability	Redundancy and distributed architecture, similar to N+1 with no single points of RF failure.	Operational hours (effective MTBF) with minimal downtime risks.
Mission-Critical Uptime	"Always On Air" operation in the event of component or amplifier drawer failure.	Continuous broadcast with high availability.
Low Total Cost of Ownership	Modular design reduces upfront costs and maintenance expenses.	Lower capital expenditure and lifecycle costs compared to non-modular systems.
Repairs	15-minute amplifier drawer swaps. No specialized training required.	Reduced repair time and labor costs for mission-critical environments.
Scalable Power	Add 2U amplifier blocks or entire racks. Combiner will need changing.	Flexible power expansion without system redesigns.
Waveform Flexibility	Latency adjustments and complex modulation support.	Signal agility for dynamic mission requirements.
Future-Ready Architecture	High speed processing and FPGA design allows DSP inside the amplifier.	Long-term adaptability to new waveforms and mode scenarios, plus a roadmap of signal processing functions.
Maintenance	No high-voltage supplies, intuitive diagnostics, common GUI across the family.	Reduced technician workload and error rates during servicing.
Fractional Sparing	One or two 2U amplifier blocks + one universal controller as backups.	Lower inventory costs while maintaining redundancy.
Broadband Agility	Faster frequency hopping and wider instantaneous bandwidth.	Adaptability to dynamic spectrum requirements in real-time operations.
Integration	Web API compatibility and standardized interfaces.	System integration with reduced customization needs.

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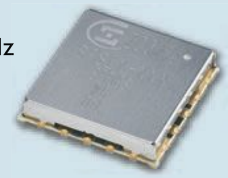

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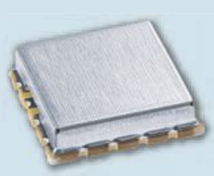

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ties, delivering precise peak and RMS power readings. Granular performance monitoring is achieved through real-time tracking of current, voltage and temperature at pallet and device levels, enabling proactive maintenance and system optimization. The amplifier is integration-ready, featuring a Web API that supports communication and third-party system control. The system employs an internal network to connect to each amplifier drawer. To avoid multiple CAT6 cables and connection faults, the system uses a root switch and rapid spanning tree protocol to provide internal network redundancy and enhance operational reliability.

The architecture utilizes full backplane implementation, eliminating the need for cable or harness detachment during service. This simplifies maintenance and ensures compliance with EMI/RFI standards, reducing potential interference and improving overall system robustness. RF power is aggregated using in-house designed combiners, while a patented fiber-optic data bus provides noise-resistance and high data rates.

The benefits of this system architecture, summarized in ***Table 1***, include its modular design, which enables fractional system sparing. This prevents users from needing a second identical system for backup, lowering the cost of ownership. For example, two 2U amplifier drawers and one controller represent a full system backup. The transmitter stays online while technicians service or replace individual amplifiers. Additionally, no specialized technician training is required and there are no dangerous high voltages to contend with. This significantly reduces maintenance and training expenses compared to TWT-based and non-modular solid-state systems.

The 2253 SSPA provides adaptability for evolving mission requirements through its waveform versatility, which supports modulations and frequency hopping to meet dynamic operational demands. Scalable power ensures seamless expansion via 2U amplifier drawers or full rack additions, enabling capacity growth without system redesign. Advanced waveform control delivers low-latency adjustments of complex digital modulation schemes and dynamic operational mode changes. Additionally, the future-ready architecture incorporates opportunities for signal processing enhancements aligned to a structured technology roadmap, ensuring performance and compatibility with emerging requirements. Together, these features position the system as a long-term, high-flexibility solution for advanced communication applications.

The significance of solid-state, high power transmitters for satcom, telemetry, tracking and command and space EW applications cannot be overstated. Increasingly complex waveforms, spectrum management requirements and multi-mission demands on ground-based infrastructure and deployed systems require intelligent amplifiers that combine high performance RF, thermal management and embedded computing control. Empower's 2253 SSPA and patented architecture support these demands.

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Los Angeles, Calif.
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Surface-Mount mmWave Block Converter With Integrated Digital Control

Spectrum Control
Fairview, Pa.

Modern electronic warfare, radar and signal intelligence systems are under increasing pressure to detect, process and respond to signals across increasingly wider spans of the RF spectrum. While most current direct sampling architectures effectively support the 2 to 18 GHz band using high speed field programmable gate arrays (FPGAs), adversarial systems now operate in higher frequency ranges, including the 18 to 40 GHz mmWave band. Spectrum Control has developed a new mmWave block converter in a compact, system-in-package (SiP) form factor that utilizes an integrated miniaturization design to address the modern battlefield and stringent size, weight, power consumption and cost (SWaP-C) directives.

Systems operate at mmWave bands because higher frequencies offer greater data throughput and more resilient communications, opening new techniques in radar and sensing. However, directly digitizing signals in this higher band is beyond the reach of many existing direct RF systems due to their ADC and FPGA performance limitations.

To unlock the full potential of wideband situational awareness, next-generation front-end architectures must bridge the gap between high frequency sensing and practical, power-efficient digitization. The new mmWave block converter from Spectrum Control fills that gap. The device converts wideband mmWave signals in the 18 to 40 GHz range down to the standard 2 to 18 GHz band, enabling integration with existing direct RF signal chains.

BIG PERFORMANCE, SMALL PACKAGE

The new mmWave block down-converter features a compact 30 × 30 mm package, as seen in ***Figure 1***. Despite its small size, it includes a 2-channel down conversion circuit, demonstrated via block diagram in ***Figure 2***, with:

- Ten precision RF amplifiers to condition and buffer signals
- Two software-controllable digital attenuators for flexible gain control
- Eleven integrated RF filters to reduce spurious content and out-of-band noise
- An RF detector for real-time signal monitoring and feedback control.

The Spectrum Control mmWave block converter delivers high performance to meet the mission-critical requirements of modern defense systems. ***Table 1*** shows the complete specifications for the 2-channel mmWave down-converter.

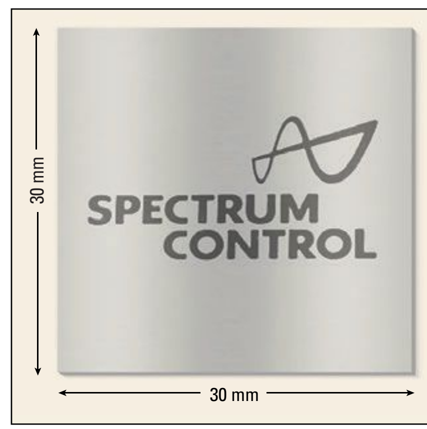

Fig. 1 **The down-converter SiP's BGA package.**

Management and control are handled by an integrated Altera FPGA with an open standard interface allowing system-level integration and mission-driven reconfiguration. A single 9 V DC power input drives the entire module, simplifying power distribution in constrained systems. ***Figure 3*** shows a

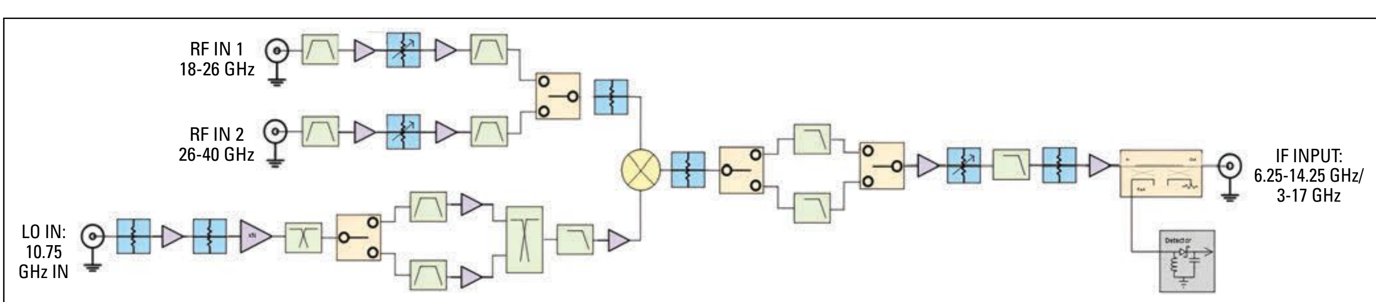

Fig. 2 **Block diagram of conversion circuit.**

TABLE 1 SPECIFICATIONS FOR MMWAVE DOWN-CONVERTER

Description	Specification		Units
	Band 1	Band 2	
Input Frequency Range	18 to 26	26 to 40	GHz
LO Frequency	10.75		GHz
Output Frequency Range	6.25 to 14.25	3 to 17	GHz
Gain	22 to 28		dB
Gain Flatness	+/- 3		dB
Noise Figure	7	9	dB
OP1dB	10	10	dBm
OIP3	19	20	dBm
Input Gain Control	26		dB
Input Gain Control Step Size	0.5		dB
Output Gain Control	26		dB
Output Gain Control Step Size	0.5		dB
Attenuator Settling Time	1		µs
Switching Speed *Fast Mode*	100		ns
Switching Speed *Low Spur Mode*	10		µs
Current (+9 VDC), *All Amplifiers Active*	1700		mA
Current (+9 VDC), *Unused Band Amplifiers Disabled*	1300		mA
Operating Temp. Range	-40 to +85		°C

diagram of the input and output elements.

It is ideally utilized as a co-processor to direct sampling devices and FPGAs or as a front-end to Spectrum Control's 3U VPX microwave wideband tuner/transceiver. It can be used in any mmWave application where SWaP-C is a primary consideration. Because it is a surface-mount device, engineers can model and integrate the block converter into a more efficient design and manufacturing process for overall time-to-market benefits.

BUILT ON SPECTRUM CONTROL'S PROVEN SIP PLATFORM

This mmWave block converter is the latest addition to Spectrum Control's expanding portfolio of RF SiP solutions. Other products include a wideband front-end (RFFE), mmWave up-converter and low jitter clock source with clock management.

Key platform advantages of the SiP platform include:

- A modular design library of RF and digital building blocks, enabling simulation and system-level customization
- High performance miniature passive structures, including advanced filtering topologies
- Packaging technologies that deliver 70 dB of channel-to-channel isolation to minimize crosstalk
- Advanced thermal management strategies and heterogeneous substrate layering, using standard microelectronics manufacturing flows
- Integrated digital control via FPGA with standardized software interface
- Onboard power management, eliminating the need for external regulators or converters.

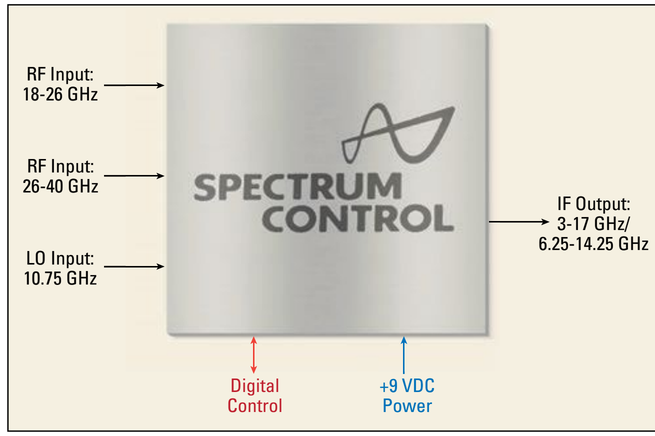

Fig. 3 Input and output diagram.

A FOUNDATION FOR FUTURE-READY SYSTEMS

Whether deployed in low SWaP-C defense systems, distributed RF sensor networks or airborne payloads, Spectrum Control's mmWave down-converter SiP enables RF coverage, system integration and digital control. It is more than a component, it is a key element for the next generation of agile, spectrum-dominant platforms.

Spectrum Control
Fairview, Pa.
www.spectrumcontrol.com

Fiber-Optic Cable Assemblies for Harsh Environments

Pasternack, an RF, microwave and mmWave provider, expanded its product portfolio to launch its first line of fiber-optic cable assemblies. The new products encompass various solutions for telecommunications, data centers, military and aerospace and other markets that demand high speed, high-reliability connectivity solutions. Pasternack offers these solutions in both custom and standard lengths with same-day shipping.

These fiber-optic cable assemblies include simplex and duplex cables with LC, SC, ST and FC connectors and are available in multimode OM1, OM3, OM4, OM5 and single-mode OS2 configurations. The fiber-optic cable assemblies allow connectivity and data transmission to support high speed data transfer needs while providing a scalable solution for future network demands.

Pasternack's fiber-optic cables are designed to endure harsh environments such as extreme temperatures, vibration, moisture and mechanical stress. These conditions are common in industrial, military, aerospace and outdoor deployments where performance and resilience are non-negotiable.

Each cable is crafted from fiber materials for signal clarity and minimized loss. Pasternack's commitment to reliability and rapid deployment makes these fiber-optic cable assemblies a solution for demanding applications across the globe.

Pasternack is a global supplier of RF, microwave and mmWave components including amplifiers, cable assemblies, connectors, adapters and other passive and active RF, microwave and mmWave components. Pasternack's products are used across the spectrum of electronics-based applications including instrumentation, military electronics, radar, telecommunications equipment (including wireless, land mobile radio and DAS), avionics, medical, industrial, transportation equipment, test and measurement, research and development labs and many other critical applications where product quality and reliability are of the utmost importance.

VENDORVIEW

Pasternack, an Infinite Electronics brand
Irvine, Calif.
www.pasternack.com

Solid-State Amplifier Operates to 3000 W

Exodus Advanced Communications presents the AMP20162, a high-power, solid-state amplifier designed for low frequency applications, including radiated susceptibility (RS103), EMI/RFI lab and general broadband testing. Covering 10 kHz to 250 MHz, this wideband system ensures signal integrity and flat response, making it a reliable choice for demanding environments.

The AMP20162 provides between 2500 and 3000 W, typical, across the frequency range and boasts a P1dB of 1700 W. Utilizing a Class A/AB design, the AMP20162 supports all modulation types and 64 dB gain while maintaining harmonic performance around -20 dBc, spurious emissions around -60 dBc and stable power with 3 dB peak-to-peak flatness.

For advanced monitoring and control, the AMP20162 integrates digital monitor and control (DMC) with real-time calibrated power indication. Users can optionally track real-time forward or reflected power, VSWR, voltage, current and system temperature through the large touchscreen or via available remotes. Available remote interfaces include Ethernet, USB, RS422, RS485, RS232 and GPIB. Gain control in the >20 dB range is accessible both locally and remotely.

Designed for rugged reliability, the AMP20162 features rack integration for simplified maintenance. The input line employs a Type-N female input connector with optional Type-N sampling ports. For higher power handling, the output port has a female 7/16 connector. Additionally, unique closed-loop, air-liquid, quiet-cool technology provides thermal management for continuous operation.

Exodus Advanced Communications specializes in LDMOS, GaN HEMT and GaAs technology and manufactures a variety of hardware, including high power amplifiers, broadband amplifiers, pulse amplifiers for radar and HIRF, low noise amplifiers and multi-band systems spanning from 10 kHz to over 75 GHz.

VENDORVIEW

Exodus Advanced Communications
Las Vegas, Nev.
exoduscomm.com

MOSFETs and ICs Enabling Mission-Critical Systems

Infineon IR HiRel offers a broad portfolio of high-reliability power management and conversion solutions designed to enhance the performance, efficiency and power density of rugged electronic systems. Infineon leverages decades of expertise and experience in high-reliability and radiation-hardened power electronics technology with a recognized power management portfolio.

Infineon's high-reliability power metal oxide semiconductor field-effect transistors (MOSFETs) are built on rugged and proven MOSFET technology, available in a range of voltages from 200 to 1000 V and industry-standard hermetic packages. These devices are qualified to industry standards, including MIL-PRF-19500 JANTX and JANTXV or equivalent, with multiple parts available as DLA QPLs.

The isolated package design of high-reliability power MOSFETs offers several benefits, including thermal efficiency, reduced drain capacitance and enhanced safety. This design also removes the need for additional isolating material between the device and the heat sink, further strengthening the system's overall performance. Infineon's high-reliability power MOSFETs are available in single, dual and quad configurations, as well as N- and P-channel variants, providing customers with a range of options to suit their specific design needs.

Infineon additionally offers high-reliability power ICs engineered for demanding environments. These power ICs feature hermetic packaging, floating channel design and tolerance to negative transient voltage, dv/dt immune. With independent high- and low-side referenced output channels, the high-reliability power ICs provide flexibility and control, allowing customers to optimize their system design for maximum performance.

Infineon IR HiRel offers a COTS+ engagement model, allowing customers to connect with regional sales managers and field applications engineers to discuss adapting Infineon's commercial portfolio for high-reliability applications. For designing a new system or upgrading an existing one, Infineon's high-reliability power MOSFETs and power ICs provide solutions for various power management needs.

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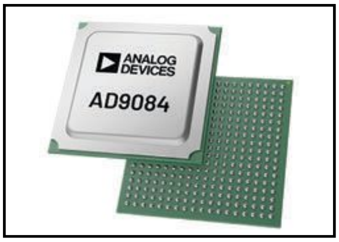


Apollo MxFE™ Breakthrough UWB Sensor for X-Band Radar and EW

VENDORVIEW

Apollo MxFE is ADI's newest ultra-wideband sensor platform specifically developed for S-Band, X-Band radar and electronic warfare applications. It has an RF input bandwidth of DC to 18 GHz, instantaneous bandwidth of up to 4 GHz per channel, significant power efficient DSP and best in class spurious free dynamic range.

Analog Devices
www.analog.com/en/products/ad9084.html

High Performance Antennas and Radomes

Axillon Aerospace (Baltimore) is an industry leader that specializes in the design, development, production, testing and repair of high performance antennas and radomes. Their antennas and radomes are utilized for various electronic warfare (EW), satellite communications (SATCOM), signals intelligence (SIGINT) and communication, navigation and identification (CNI) applications. Axillon products can be found across all domains, assisting the U.S. military and its allies in achieving electromagnetic spectrum superiority.

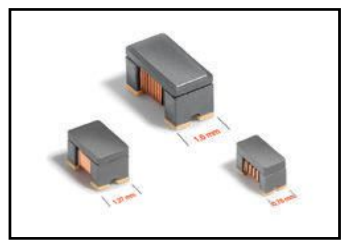
Axillon Aerospace
www.axillonbaltimore.com

Thermoelectric Refrigeration Cooling/Heating System

VENDORVIEW

Cernexwave's Thermoelectric Refrigeration Cooling/Heating System is a great solution to bring your components to the optimum temperature for testing. They have a temperature control range of -45°C to +120°C with fast temperature change speed and high accuracy. The large cooling/heating plate dimensions and small overall footprint allow these units to be used for a great range of components in labs of any size.

Cernexwave
www.cernexwave.com



Outgassing Compliant USB Common Mode Chokes from Critical Products & Services

FRA Family common mode chokes virtually eliminate common mode noise in high speed, differential-mode signal transmission applications such as USB 3.0, HDMI, SATA, IEEE1394 and LVDS, supporting data rates up to 4.8 Gbit/s. They are offered in three standard sizes, 0603 (AR312FRA), 0805 (AR336FRA) and 1206 (AR376FRA), all of which pass NASA low outgassing specifications. The use of a chemically resistant adhesive also helps these parts withstand aggressive solvents.

Coilcraft
www.coilcraft.com

Elve mmWave Amplifier First Light Demonstration Program

Elve unlocks access to high power and high efficiency mmWave amplifiers in Ka-, Q-, V-, E- and W-Bands for multi-domain applications. Elve products enable Gbit speeds for next-generation multi-domain connectivity with large-scale production of TWTAs at significantly lower costs. Experience Elve mmWave amplifiers risk-free with the new two-month free hardware "First Light" product demo program.

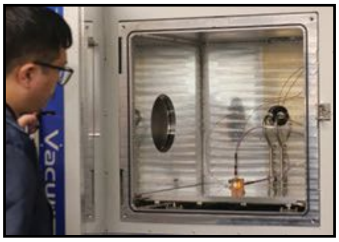
Elve, Inc
elvespeed.com/firstlight

Empower RF SSPA Modules Boost C-UAS Defense

VENDORVIEW

Empower RF provides a suite of SSPA modules for full bandwidth coverage into fielded C-UAS jammers. Covering 500 to 6000 MHz, the 1193, 1211 and 1212 models have identical mechanical dimensions. Each features the RS-485 interface for superior digital control and monitoring, these modules provide ease of integration. With tactical reliability, Empower's modules are a popular choice for systems that jam communication links, interfere with GPS or spoof. Perfect for handheld, fixed-site or mobile systems.

Empower RF
www.empowerrf.com/amplifier-notes/modules-counter-UAS.php

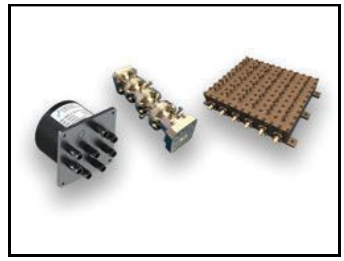


mmWave Thermal Vacuum Testing Services

VENDORVIEW

Introducing Eravant's mmWave Thermal Vacuum Component Testing Services. Simulate the extreme temperature ranges and vacuum conditions required for mmWave component testing for space qualification. The 24 × 24 × 24 in. chamber allows for testing from -160°C to +250°C with an operating vacuum pressure up to 1 × 10^{-6} torr. In addition, a variety of in-house test equipment and components from DC to 110 GHz are available for customer use, including specialized coaxial vacuum RF feedthroughs from SMA to 1 mm.

Eravant
www.eravant.com/products/services/chamber-testing



High Performance Passive Components

VENDORVIEW

Exceed Microwave provides custom high performance passive microwave component designs up to 110 GHz for defense, space and commercial applications. Exceed Microwave is AS9100 certified and ITAR registered, providing high-quality, high performance passive components. They provide various types of designs, each with its own unique values and are designed and made in the U.S. Many of Exceed's designs offer extremely high Q factor, allowing very low insertion loss and high-power handling.

Exceed Microwave
www.exceedmicrowave.com

AMP20052, 20 – 500 MHz, 1000 W

VENDORVIEW

Exodus AMP20052 is designed for EW/ECM, EMI/RFI, lab and general communications applications. With a Class A/AB linear design, 1000 W minimum with 60 dB gain. Features high-power advanced technology devices for instantaneous bandwidth. Optional monitoring for forward/reflected/VSWR indication as well as voltages and currents. High efficiency, with unprecedented reliability and ruggedness in a 6U chassis.

Exodus
www.exoduscomm.com

T1354 TCXO

The T1354 temperature-compensated crystal oscillator (TCXO) is available from 20 to 100 MHz and features an extremely rugged, 20.3 x 12.7 mm DIP package, clipped Sine output and supply voltage of +3.3 or +5.0 VDC. The T1354 is radiation tolerant to 100 krad (Si) TID, and an ultra-low g-sensitivity option is available for appropriate applications. Frequency stability versus temperature is ± 1.0 ppm (-20 to 70°C). The T1354 Series has been designed for low orbit satellite applications (nano/micro satellites), RF telemetry systems, multiband terminal and up-converter applications.

Greenray Industries
www.greenrayindustries.com

Precision and Flexibility for Defense Applications – HASCO's Littlebend Cable Selector Guide

VENDORVIEW

HASCO components delivers mission-ready performance with its Littlebend RF cable line, engineered for tight-space, high frequency defense systems. Now, selecting the right solution is easier than ever with HASCO's Littlebend Cable Selector Guide — a streamlined tool to compare specifications like bend radius, insertion loss, and shielding effectiveness across configurations. Ideal for electronic warfare, radar, and secure communications, Littlebend® Cables offer unmatched flexibility and performance.

HASCO
hasco-inc.com/littlebend-selection-guide

HYPERLABS Launches Next-Generation Test Instruments

VENDORVIEW

The HL10300 Multifunction Pulse Generator is the first product to be released on HYPERLABS NextGen Instrument Platform. The HL10300 offers unique DC-coupled outputs that provide up to 8 Vp-p (Single Ended) 16 Vp-p (Differential). The pulse generator offers a rise time/fall time of < 25 ps (20/80 percent), an adjustable pulse width of 50 ps to 105 µs and < 400 fs of jitter. The repetition rate can be adjusted from 1 mHz to 625 MHz (up to 2.5 GHz in Impulse Mode).

HYPERLABS INC.
www.HYPERLABS.com/product/HL10300/

Ruggedized Power Products

Infineon IR HiRel brings highly reliable DLA-qualified power solutions to the A&D market. Their portfolio of ruggedized power products includes discrete MOSFETs, power ICs and IGBTs are all manufactured in U.S.-based MIL-PRF qualified facilities. Infineon's MOSFETs, available in both N- and P-channel, are offered in a wide range of voltages as high as 800 V. Their top-performing power solutions include the single-channel MOSFETs, popular among customers for their low on state resistance, high trans conductance, voltage control, fast switching features and temperature stability.

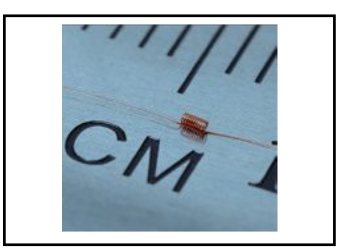
Infineon IR HiRel
www.infineon.com/dgdl/Infineon-IR_HiRel_defense-ProductSelectionGuide-v01_00-EN.pdf?fileId=8ac78c8c93dda25b01945e1b26de0a10

50 Years of Cutting Edge MIL-Spec Components: DC-110 GHz

VENDORVIEW

KRYTAR focuses on designing and producing ultra-broadband MIL-Spec components catering to a wide range of defense electronic applications, including test equipment; simulation systems; satcom and SOTM; radar and IED jammers; radar systems; electronic warfare: ECM, ECCM and ESM; and quantum/cryogenic. KRYTAR products are designed and manufactured in the U.S. Whether perfecting wireless networks, satellite communications, advancing defense systems or exploring space, KRYTAR delivers off-the-shelf and custom solutions designed to meet your specific needs with unparalleled precision, quality and reliability.

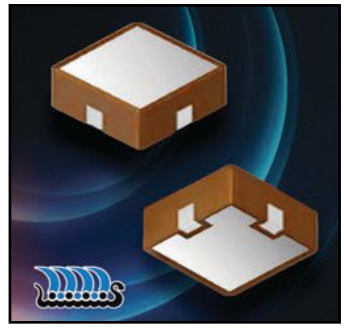
KRYTAR
www.krytar.com



Miniature Air Coils for High Reliability, RF and Microwave Applications

Microwave Components, Inc. (MCI) in Dracut, Mass., is a small, veteran-owned manufacturer of miniature air coils. MCI has proudly been delivering custom, high Q, miniature air inductors to the aerospace, defense and space markets since 1978. Materials include bare and insulated gold, copper, silver, gold plated copper, nickel copper alloy and aluminum wire. Inductances from 1 to 1000+ nH.

Microwave Components, Inc.
www.mcicoils.com



Directional RHCP RF Chip Antenna

Johanson's directional RHCP RF chip antenna is built for 2.4 GHz automotive applications. AEC-Q200 qualified, it ensures strong, focused signals with high detuning resilience. Ideal for vehicle tracking, access, positioning and IoT. Works with Johanson's hybrid coupler for stable, multipath-resistant connectivity from -40°C to +105°C. Mounts easily on edge, corner or center of PCBs. Perfect for Bluetooth, Wi-Fi, Zigbee, Thread and LoRa. Improve wireless performance in today's smart vehicles with this rugged, high performance solution. P/N: 2440AT62B0085002U. Ask for an eval board.

Johanson Technology
www.johansontechnology.com

Pulse and Pulse Profiling Power Meter for Defense Systems

VENDORVIEW

The LB680A high performance 50 MHz to 20 GHz pulse profiling power sensor offers a range of advanced features for radar communications, R&D, manufacturing and service applications. In addition to its pulse profiling capabilities, the sensor provides statistical pulse measurements and can make 2,000 settled average power measurements per second, making it ideal for source calibration and antenna testing. Add option OW2 for wideband detector output. Includes LadyBug's Power Meter and Pulse Profiling Applications.

LadyBug Technologies
www.ladybug-tech.com/product-category/wideband-pulse-profiling-sensors-50-mhz-to-20-ghz/

EMI-Filtered Components

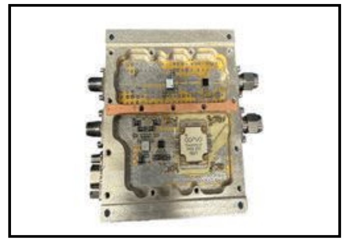
Electromagnetic interference (EMI) threatens performance and security in aerospace and defense systems. Molex's EMI-filtered components, including high performance EMI D-sub connectors, EMI filter plates, custom circular EMI filter connectors and RF coaxial attenuators and terminations, offer vital protection by blocking noise and preserving signal integrity. Using advanced filtering techniques, Molex products ensure reliability and durability in extreme environments, safeguarding mission-critical operations. Trust Molex expertise to keep your systems secure and efficient.

Molex
www.molex.com

RX13106 EW Tuner

MPG Solutions® RX13106 EW Tuner sets a new standard for compact, high performance signal intelligence. Covering 0.5 to 18 GHz with 1 GHz instantaneous bandwidth, it delivers fast 10 μs tuning, 50 dB SFDR and advanced preselection filtering. Optimized for ELINT, SIGINT and RESM operations, the modular design and phase-coherent multi-channel option make it mission-ready for the modern battlefield, bringing superior clarity and adaptability to your electronic warfare system. Fully customizable, MPG Solutions® EW Tuner can elevate any mission. Connect with us today.

MPG Solutions
www.mpgdover.com/en/products-and-solutions/solutions/receivers/MPG-Solutions-EWTuner.html



New Ku-Band CDL Front End TX/RX Solution

Mtron announces the launch of its new Ku-Band CDL Front End TX/RX Solution, a compact, lightweight airborne package that integrates cutting-edge GaN technology. Featuring a 30 W CW solid-state power amplifier with a 40 percent PAE, the solution offers unmatched performance. Key attributes include superior band-to-band isolation of 110 dB and an ultra-low noise figure LNA (< 1.5 dB). This innovative solution sets a new standard in airborne communication, combining high power efficiency with exceptional signal clarity in a compact, reliable package.

Mtron
www.mtron.com

Space-Grade Filters and Integrated Assemblies

Introducing NIC's space-grade filters and integrated assemblies, leveraging LC, ceramic, cavity, and crystal filter technologies — engineered for exceptional performance across all mission profiles, from short-duration CubeSats to decades-long deep space and GEO missions. Designed for universal space deployment, these components meet MIL-STD and NASA-EEE standards, offering full pedigree and traceability. With hermetically sealed construction, low insertion loss and high Q-factors, they ensure long-term reliability in the harshest environments. Extensively qualified through thermal cycling, vacuum, and vibration testing, they are the trusted solution for any mission.

NIC
www.nickc.com

New SOSA Aligned ATR Enclosures

Utilizing the 3U OpenVPX form factor, the various chassis platforms typically support 100GbE or higher speeds. The new ARINC 404 5/8 size ATRs from Pixus features customized I/O options and various SOSA slot profile options, including RF and optical interfaces through the backplane. For chassis management, the ATR has the option of implementing Pixus' SOSA aligned Tier 3 mezzanine-based solution that sits behind the backplane. This saves a slot of space while acting as a health monitor and control module for the system.

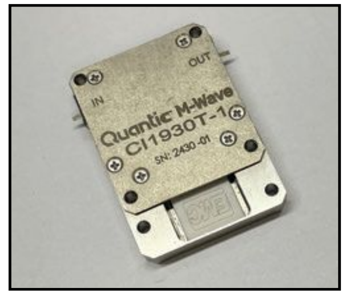
Pixus Technologies
www.pixustechnologies.com

Qorvo® Launches New Ku-Band Beamformers for High Performance SATCOM Terminals

VENDORVIEW

Qorvo's latest beamforming ICs provide a competitive edge with low noise figure, enhanced temperature stability and simplified system integration. Designed for high channel efficiency, these BFICs optimize link budgets and reduce power consumption — delivering superior performance for next-generation SATCOM networks.

Qorvo
www.qorvo.com/go/satcom?utm_source=qorvo&utm_medium=ad-bonus-supplement&utm_campaign=satcom_2025



Mil-Aero and Space-Qualified Passive Components

For over 35 years, M-Wave Design (now part of the Quantic portfolio), has delivered solutions for aerospace and defense systems. We offer a vast library of high-power, low loss passive components in connectorized, stripline and wave-guide topologies. Contact our sales team and learn how we can support your specific application needs!

Quantic M-Wave
www.quanticmwave.com

Whisper Series Phase Locked DROS

VENDORVIEW

Designed to meet and exceed stringent system requirements, Quantic MWD's (Microwave Dynamics) Whisper Series PLDROs deliver exceptional frequency stability and low phase noise performance, even in the harshest conditions. Available in X-Band and Ku-Band frequencies ranging from 8 to 18 GHz, these oscillators can be fully customized with phase locked loops and tuning for enhanced performance. Low phase noise of -110 dBc/Hz at the 10 kHz offset and -105 dBc/Hz at the 1 kHz offset.

Quantic MWD
www.quanticmwd.com/product/whisper-series/

Solid-State Power Amplifiers

VENDORVIEW

Quantic PMI's Solid-State Power Amplifiers (SSPAs) are ruggedized for use in pulsed airborne, naval and ground radar applications, as well as found in weather forecasting Doppler radar systems and utilized in air traffic control and precision approach radar systems. These power amplifiers offer remarkably high gain up to +53 dB and saturated output power above 40 dBm (10 W) in bandwidths up to 40 GHz. Many options are available including RoHs and COTS options.

Quantic PMI
www.quanticpmi.com/categories/power-amplifiers

QPP Series Pulsed GaN SSPAs

QuinStar's QPP Series Pulsed GaN SSPAs deliver high peak power, fast rise/fall times and low droop for instrumentation radar, including weather and RCS testing. Engineered for pulsed/CW modes, they outperform tube amplifiers with higher reliability, smaller footprints, with no warm-up time. Available at 94 GHz and ~35 GHz, these compact, U.S.-built, MIL-qualified SSPAs are trusted in defense and lab environments where performance, uptime and precision matter most.

Quinstar Technology
www.quinstar.com

RF and Microwave Filters and Integrated Assemblies

VENDORVIEW

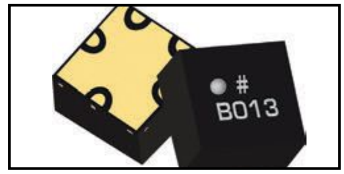
Reactel manufactures a line of filters, multiplexers and multifunction assemblies covering up to 67 GHz. From small, lightweight units suitable for flight or portable systems to high-power units capable of handling up to 25 kW, connectorized or surface-mount — their talented engineers can design a unit specifically for your application.

Reactel, Inc.
www.reactel.com

Custom BUC and BDC for Satcom

Renaissance Electronics specializes in high frequency BUC and BDC solutions for satcom. Our converters feature fixed and programmable LO, with up-converters offering an integrated power amplifier option. A prime example is our Ka-Band BUC and BDC, designed for high reliability with customized output power, low noise figures and flexible frequency plans. Key features include an integrated 25 W PA BUC, fixed frequency plans for simplicity and BDC band switching from 18 to 40 GHz. Optimize your communication systems with Renaissance.

Renaissance Electronics
www.rec-usa.com/



Wideband 1:2 Balun for High Performance ADC and Beamforming Systems

VENDORVIEW

Available now at RFMW, the Marki Microwave MBAL-0R520CSP2 is a GaAs passive MMIC 1:2 balun operating from 0.5 to 20 GHz with exceptional 31 dB common mode rejection. Designed for ADC/DAC interfaces, digital beamforming, clock distribution and balanced amplifiers, with optimal phase and amplitude balance of 2 degrees and 0.2 dB. Its compact 2.5 mm chip-scale package is RoHS compliant and ideal for high frequency, high-density designs. It is footprint-compatible with the 1:1 MBALH-0R520CSP2, allowing for flexible system architectures.

RFMW
www.rfmw.com/products/detail/mbal0r520csp2-marki-microwave/859540?utm_source=MWJ-spotlight&utm_campaign=2025June-Marki&utm_medium=digital-print

San-tron Releases New 1.0 mm Adapters, Cable Connectors and Cable Assembly Products

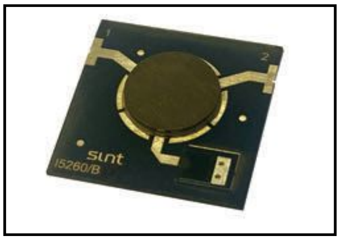
San-tron has released a new family of 1.0 mm connector products that perform mode-free up to 110 GHz. The family of high frequency interconnects is comprised of both in-series and between series adapters, male and female cable connectors for 047 coax cable as well as full cable assemblies using 047 flexible cable. Primarily used for test and measurement applications these products are rugged and reliable for measuring high frequency signals.

San-tron
www.santron.com/products/series/1.0mm-110-ghz

USB-Powered VNA

The VNA400, Signal Hound's new 40 GHz, two-port, USB-powered vector network analyzer, samples incident and reflected signals on both ports simultaneously. With excellent dynamic range (up to 125 dB), sub-Hz resolution, ± 1 ppm internal TCXO accuracy and fast sweeps (2000 points per second at 30 kHz RBW), the VNA400 is optimized for testing two-port devices, such as filters, amplifiers and attenuators, as well as one-port devices like antennas or VSWR testing in the lab or out in the field.

Signal Hound
www.signalhound.com



Increased Performance and Density for AESA Radar at Lower Costs

Radar designers are being challenged to increase performance and density without significantly impacting cost. Trusted by leading radar manufacturers, Smiths Interconnect offers a range of SMT circulators and isolators with class-leading RF power linearity and minimized size designed to lower costs through pick-and-place AESA integration; e.g., 25 W_{pk} 0.6 g, 1.6 mm high 5.2 to 6 GHz isolator.

Smiths Interconnect
smithsinterconnect.com

3U VPX Multi-Channel Converter

Teledyne Microwave Solutions' new 3U VPX Multi-Channel Converter offers two wideband transceivers on a single 3U card. RF coverage is from 0.5 to 20 GHz, 2 GHz IBW with excellent phase noise of -124 dBc/Hz at 1 MHz offset. Rugged, compact and reliable, it is an ideal solution for radar warning receivers and jammer systems.

Teledyne Microwave Solutions
teledyne-ade.com/Microwave-Solutions-RFM

Miniature, High Performance mmWave Block Converters

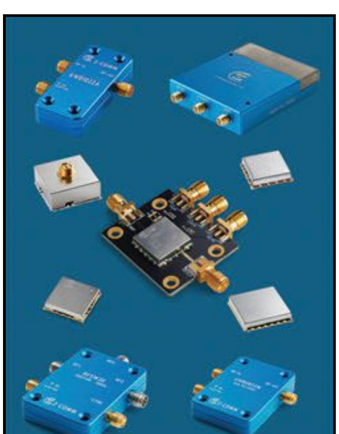
New miniature systems-in-package from Spectrum Control deliver high-fidelity block conversion: down-conversion (PN:SCRS-00-1001) and up-conversion (PN:SCRS-00-1003) of wideband mmWave signals (18 to 40 GHz) into the 2 to 18 GHz band. 30 mm^2 BGA package. Integrated power supply with single +9 VDC input (down-converter) or dual +9 VDC and +5 VDC inputs (up-converter). Integrated digital gateway for software-defined monitoring and control. Spectrum Control's SiP platform offers standard and custom software-definable RF+ system blocks that reduce the size and complexity of today's integrated RF + digital systems.

Spectrum Control
www.spectrumcontrol.com/products/rf-digital-blocks/rf-sips

Designed for Durability. Engineered for Excellence.

Trexon solves the world's most challenging connectivity problems with relentless innovation, industry expertise and constant collaboration. Formed from the combination of top wire and cable companies, Trexon provides an expanding range of specialized products and solutions designed for rugged and specific conditions. The Trexon Engineered Products Group consists of the following industry-leading companies: Cicoil, EZ Form Cable, The First Electronics Corporation, Hydro Group, Integrated Cable Systems and Power Connector Inc.

Trexon Company
https://youtu.be/n9ufNoBtJ9M
https://trexonglobal.com/engineered-products/



Z-Communications, Inc. High Performance VCOs and Frequency Modules

Z-COMM has been delivering high performance VCOs for over 38 years. Z-COMM VCO products are well known for superior phase noise performance, such as -121 dBc/Hz at 10 kHz at 2500 MHz. Z-COMM provides so much more, including synthesizers, amplifiers, RF switches and phase locked oscillators. From surface-mount RF systems to lab-based, benchtop modules, let Z-COMM customize a product for your next RF design. Visit our webstore at store.zcomm.com.

Z-Communications, Inc.
www.store.zcomm.com

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