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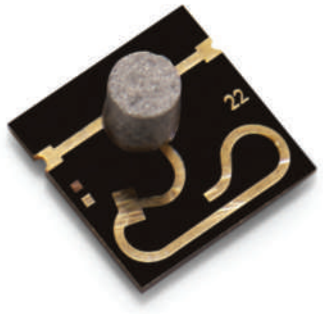

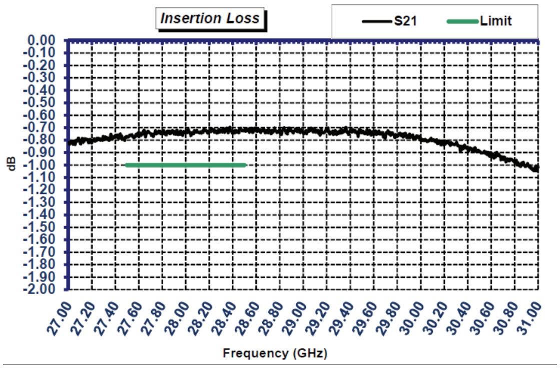

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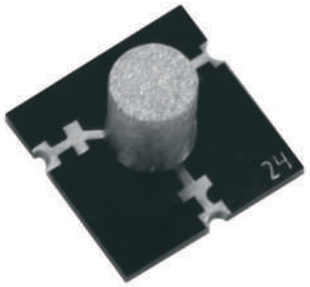

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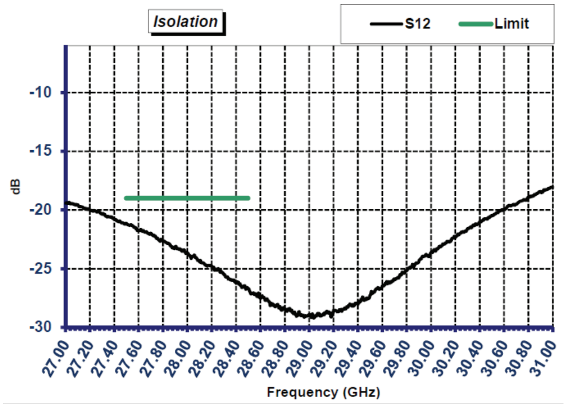

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CONTENTS

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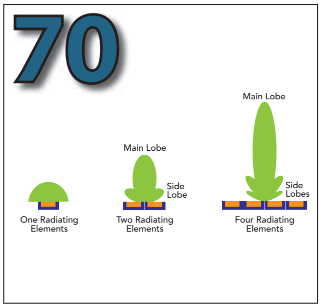

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Cover Feature

Perspective

Technical Features

64 YEARS OF PUBLISHING EXCELLENCE

Microwave Journal CONTENTS

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Product Feature

Tech Brief

Departments

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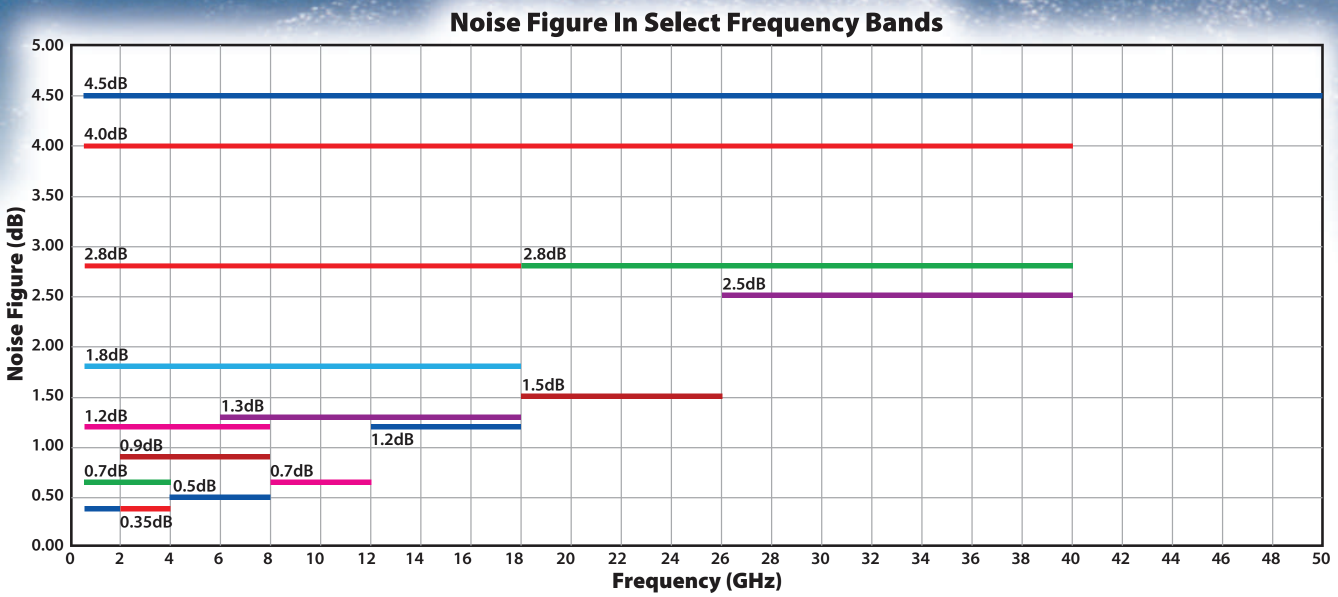


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UWB: Enhancing Positioning, Safety and Security for Connected Vehicles

Kerry Glover and Bror Peterson
Qorvo, Greensboro, N.C.

Ultra-wideband (UWB) is an RF wireless technology that could enhance advanced driver assistance systems (ADAS) and connected autonomous vehicle (CAV) sensor suites. The addition of UWB could increase the number of lives saved by avoiding deadly collisions and ensuring the trusted rollout of vehicle-to-everything (V2X) connections.

Technology advancements are changing our everyday lives and significantly impacting whole industries. This holds true for the automotive industry, which continues to adopt new technologies to enhance consumer experiences, safety and security. Among today's biggest concerns are severe traffic collisions, an area where technology can be applied to save lives. Many efforts are underway to define, develop, standardize and implement the best technologies to improve road safety. Initially, manufacturers have used stand-alone ADAS technologies inside vehicles, such as radar and cameras. With these technologies, each manufacturer could implement its own system without the need for standardization.

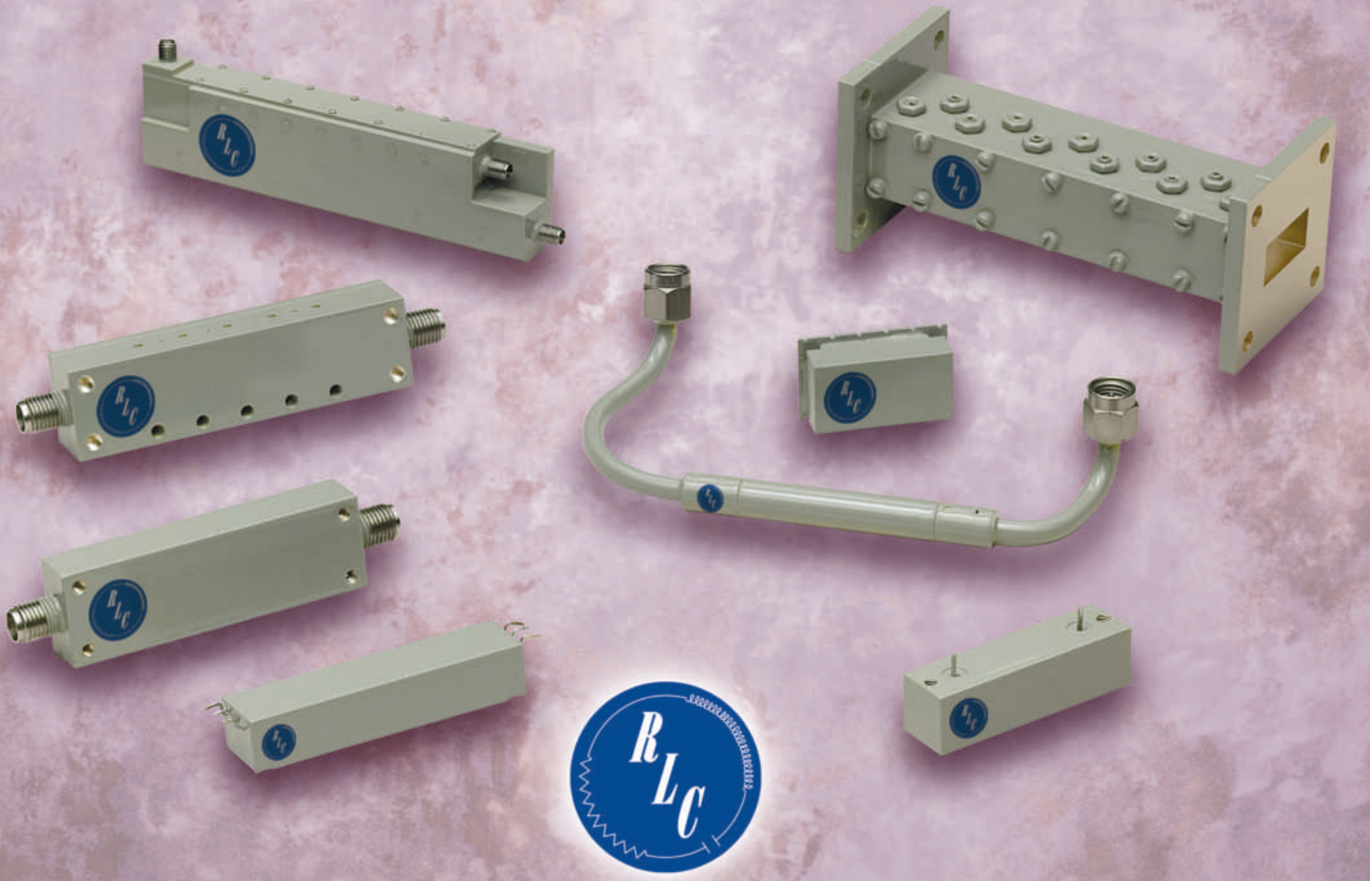
The next big leap in safety will be for vehicles to share information, enabling them to cooperate with each other. This will require standardization to ensure connectivity of vehicles from different manufacturers. Efforts are underway to provide the basis for connected vehicles by standardizing V2X connectivity, including vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and vehicle-to-pedestrian (V2P) protocols. V2X standardization efforts open the way for the adoption of new technologies that enhance the ADAS and CAV sensor suites.

UWB is a low-cost RF technology that can be used to accurately measure the distance between two points. This leads to the perfect marriage: UWB + V2X. The adoption and standardization of UWB + V2X can add capabilities, including precise positioning, secure identification and ultra-low latencies at high update rates. This article will focus on a few critical life-saving applications of UWB + V2V and UWB + V2P. However, it is important to note that there are also many applications where UWB + V2I could greatly improve consumer convenience, such as automated valet parking and alignment with electric vehicle chargers.

UWB TECHNOLOGY

IEEE 802.15.4z provides a specification for the standardization of UWB for secure ranging. The security aspects of the standard ensure distance measurements are accurate and not spoofed by external sources. UWB secure ranging works by measuring the time it takes for very narrow RF pulses to travel from a transmitter to a receiver. This "time of flight" is multiplied by the speed of light to obtain the distance. Narrow pulses enable the system to accurately understand multi-path interference and choose the first path, ensuring identification of the nearest object.

Many pulses are grouped together to form frames. Each secure ranging frame contains a scrambled time stamp, which is created using cryptographic techniques to ensure the reliability of the distance measurement. A single frame can be transmitted in less than 200 μs. Frames are sent back and forth between the transceivers of all nodes in a group, providing round-trip



distance measurements between all nodes. For a simple one-sided, two-way ranging operation, round-trip measurements can be completed in under 1 ms, enabling an update rate of 1000/s.

UWB operates with a bandwidth greater than 500 MHz and, when coupled with the proper signal processing techniques, can provide distance measurements with an accuracy down to 10 cm. All these capabilities can be implemented on a single low-cost CMOS device. More background information and an overview of UWB technology can be found in the Qorvo publication *Ultra-Wideband for Dummies*.[1]

COOPERATIVE DRIVING

The automotive industry is beginning to envision its connected future, ushering in a new era of cooperative autonomous driving. This includes use cases such as group start from traffic lights, intersection crossing, vehicle platooning and merging between lanes. These use cases require knowing vehicles' relative position to an accuracy better than 1 m and down to 10 cm in some cases. By sharing accurate positioning information, vehicles can work together to perform these functions more safely and with faster reaction times than a human, allowing them to operate with minimal or no human intervention.

One of the basic functions of V2V communications is the exchange of basic safety messages (BSM) in the U.S. or cooperative awareness messages (CAM) in Europe. These messages include information such as vehicle position, speed and heading. From this rough positional data, a vehicle's autonomous navigation system (ANS) can determine which other vehicles are in the vicinity. Groups can then be formed for cooperative maneuvers.

In complex cooperative maneuvers of connected vehicles, maintaining proper separation is imperative to avoid fatal contact between vehicles. According to the 5G Automobile Association (5GAA), a global organization working on future connected mobility and intelligent transportation solutions, precise positioning is one of the critical problems to be solved. Keeping vehicles separated requires technology that can provide exact position measurements with fast update rates.

UWB can perform this function with accuracy down to 10 cm, which is one of the reasons the technology is growing globally. UWB can also save lives by preventing collisions between vehicles and vulnerable road users (VRUs) such as bicycles, motorcycles and pedestrians. UWB is rapidly proliferating in many consumer products and applications. Many of the leading cell phones include UWB, and the technology is being added to cars to enable phones to act as secure digital keys.

Wouldn't it be great if UWB in vehicles and UWB in cell phones could be used together to save lives? If a vehicle could talk to a pedestrian's cell phone (V2P) and use UWB to measure the distance between them, then vehicle-pedestrian collisions could be avoided. UWB can increase the security of communica-

tions by preventing malicious spoofing, which is a significant concern with CAVs. By verifying a vehicle's ID and position, UWB can validate communications are with the intended vehicle instead of someone impersonating that vehicle for malicious purposes. Recent reports have demonstrated the impact of costly infrastructure blackmail exploits that have compromised many systems and led to loss of service. Can you imagine traveling down the highway in a CAV and receiving blackmail demands to pay or else the vehicle might be crashed?

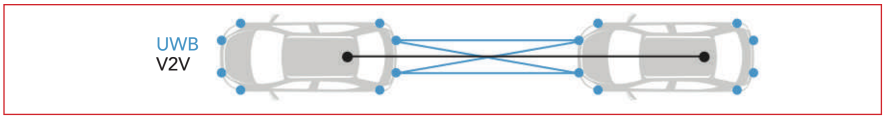


Fig. 1 Two vehicles using an UWB crossbar connection.

UWB WITH LARGE OBJECTS

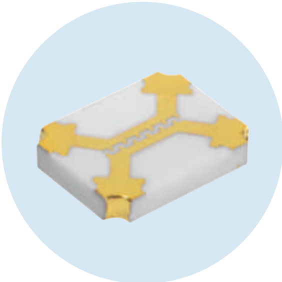
Most of the literature about UWB focuses on determining the distance to a small object. But when UWB is applied to large objects such as vehicles, knowing the distance to a single point somewhere on the vehicle is not adequate. In the case of moving vehicles, the measurements must be relative and continuous. Using multiple UWB sensors, each vehicle can continuously calculate the relative position of all four corners of another vehicle. Throughout the rest of this article, the term position will refer to relative position.

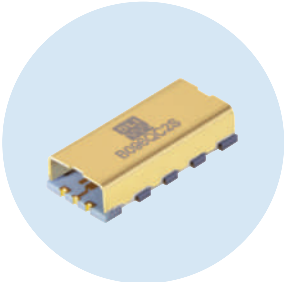
For a cooperative maneuver, the ANS could identify the appropriate vehicles and form a group using the V2V link. After a group has been formed, the ANS would identify, initialize and start continual measurements with the appropriate UWB sensors, again using the V2V link. ***Figure 1*** shows how UWB sensors near the corners of two vehicles could form a crossbar arrangement. With two sensors located on each of the front, rear and side surfaces of each vehicle, the position and orientation of both vehicles could be determined. Each of the UWB links provides a unique, secure method of measuring the precise distance, as well as supporting data communications. Data communications can further enhance security by enabling the exchange of additional details.

SAFETY AT HIGH SPEED

During high speed maneuvers involving several vehicles, it is vital that the CAVs function without failure. One common example is platooning (see ***Figure 2***), where several vehicles travel in tight formation, drafting each other to save fuel. Platooning will help the trucking industry increase safety while reducing fuel costs and emissions, as well as reducing congestion and delivering goods faster. It could also help maximize the range of electric vehicles with limited battery capacity.

UWB links enable platooning vehicles to accurately measure the distance between them and maintain proper separation and orientation. In a platoon, each vehicle follows





another at a close distance. Reaction time is critical. If the platoon is traveling at 60 m/s (135 MPH) and the separation between the vehicles is 6 m (20 ft), vehicles in the platoon must react in less than 100 ms to avoid a collision if the lead vehicle suddenly applies its brakes. This can easily be achieved with UWB.

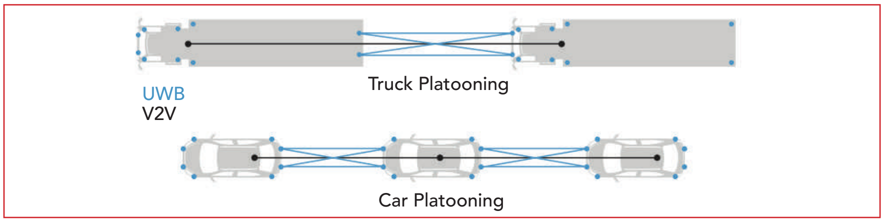


Fig. 2 Vehicle platoon using UWB to maintain separation and orientation.

With four sensors in a many-to-many UWB architecture, a ranging round should be completed in well under 10 ms, with the exact timing dependent on implementation. A ranging round is the time it would take for the four sensors to measure the four distances shown in Figure 2. For a vehicle traveling at 60 m/s, a ranging round time of 10 ms means the vehicle would travel only 60 cm between messages, giving each vehicle adequate time to react safely to speed changes of the lead vehicle. Multiple UWB links enable the platooning vehicles to maintain the correct orientation to each other. This could enable each vehicle's ANS to follow the lead vehicle around curves, staying in the same track as the lead vehicle.

VEHICLE MERGING

Merging is another process where CAVs can benefit from UWB sensors. Examples of situations where vehicles need to merge include entering a highway from an on-ramp or joining the middle of a platoon. ***Figure 3*** shows a situation where one vehicle needs to merge with two other connected vehicles. The ANS first establishes a connection using V2V, forms a group and communicates the need to merge. The system would then determine the UWB sensors needed for the operation, initialize those sensors and launch continuous UWB sensing (see Figure 3a).

The next step is for the two vehicles

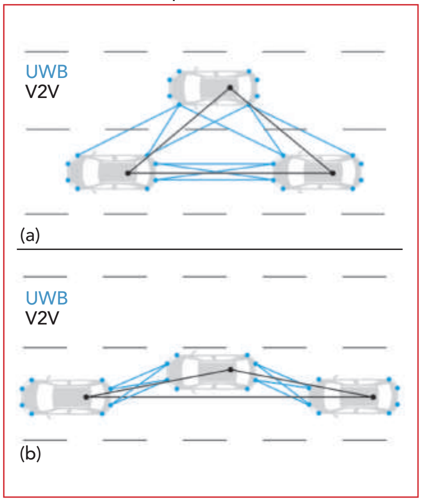


Fig. 3 A vehicle joins a vehicle group with V2V and UWB before merging (a), then completes the merge (b).

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UWB AND V2P

Another key potential life-saving application takes advantage of UWB coupled with V2P communications using a VRU's smartphone or other UWB-enabled device. This works similarly to V2V: the ANS, coupled with V2P, can determine if a VRU is in the vicinity and then start the UWB distance measurement process. UWB tracks the exact position of the VRU and determines the possibility of a collision. As an example, vehicles stopped at an intersection, such as the three-way stop shown in ***Figure 4***, could use UWB sensors to determine the distance to the VRUs and avoid a collision.

VALIDATING FOR IMPROVED SECURITY

UWB can also be used to mitigate risk for connected car threat scenarios. The Car Connectivity Consortium already includes UWB in its Digital Key 3.0 specification, which enables drivers to securely use their phones to open and start their cars. UWB increases security by measuring the distance between the owner and the vehicle. Ensuring the owner is in the proximity of the vehicle prevents "person in the middle" vehicle attacks where thieves intercept and relay distant signals from an owner's phone to gain access.

With V2V communications, it is vital for safety that vehicles can trust the information received from other vehicles. Detecting misbehaving actors transmitting inaccurate information, whether unintentionally or maliciously, is an important security and safety concern. UWB can provide the required trust between vehicles by ensuring they know each other's position, validating their identity and detecting misbehavior. This is especially important when the communication includes life-critical information. The analysis in ***Table 1*** summarizes the most critical 5GAA cooperative driving use cases where inaccurate information could be deadly.

UWB sensors could be used to verify that the vehicle being communicated with over V2V is really in the position indicated. If the position does not correlate with the GPS coordinates transmitted in the BSM or CAM, then any transaction between the vehicles would be in doubt and appropriate precautions could be taken. Identification of misbehaving actors in the system and then revoking their certification will help ensure a trusted V2V system.

In one potential example of fatal spoofing (see ***Figure 5***), a spoofing vehicle (SV) traveling behind a passing vehicle (PV) pretends to be in front of the vehicle by transmitting incorrect GPS coordinates, falsely indicating it is in front of the PV instead of behind it. If the PV requests "see through for passing" information, the SV could then transmit an

TABLE 1 SCENARIOS WHERE SPOOFING CAN BE FATAL

Spoofing Use-Cases	Location	Type	Speed	Spoof Result	UWB Safety Verification	UWB Precise Positioning
High-definition sensor sharing	Highway	ADAS	Any	Fatal	×	
See-through for passing	Passing	ADAS	High	Fatal	×	
Vehicles platooning in steady state	Highway	CAV	High	Fatal	×	×
Cooperative maneuvers of autonomous vehicles for emergency situations	Highway	CAV	High	Fatal	×	×
Cooperative lane merging	Highway	CAV	High	Fatal	×	×
Cooperative coordinated driving maneuver	Any	CAV	Any	Fatal	×	×
Cooperative traffic gap	Highway	CAV	High	Fatal	×	×

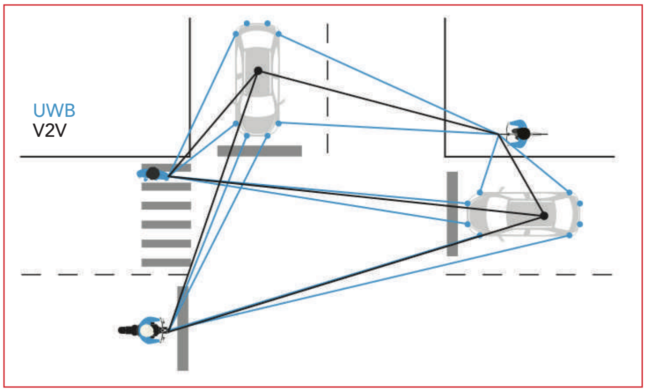


Fig. 4 Three VRUs at a three-way stop.

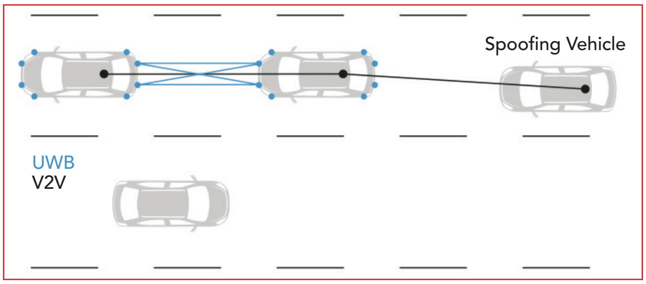
image of a clear road. Based on this false information, the PV would start to pass and could collide head-on with an oncoming vehicle. This can be avoided if the PV is able to verify, using UWB, whether the SV is truly the vehicle in front.

UWB can also be used to accurately identify vehicles in other use cases. Following directly behind two vehicles closely tailgating each other, it could be difficult to know with which of the two your vehicle was communicating. UWB distance measurement could confirm communication with the appropriate vehicle. Another example: following two vehicles traveling side by side in adjacent lanes. If one vehicle is using real-time kinematics to adjust its GPS coordinates and the other vehicle is not, the two vehicles could be reporting the same location.

AUGMENTING THE CAV SENSOR SUITE

UWB provides an excellent augmentation to the existing CAV sensor suite. Its high frame rate provides much faster reaction times than any other system. The ability to provide communications in addition to sensing enables UWB to provide secure distance measurements and accurately identify other vehicles. Being an RF technology, it operates much better than optical systems in poor weather. UWB's small size, low complexity and low cost make placing multiple sensors around a vehicle feasible.

UWB sensors offer the benefit of simplicity, which helps vehicles process and respond to information more quickly. The processing power required to implement UWB secure ranging is relatively small. To provide the same information about the relative distance and orientation of two vehicles without using UWB requires both radar and cameras. The camera would need to look at the scene, analyze the image, extract key features and determine orientation. The radar would



▲ **Fig. 5** **"See through for passing" scenario using UWB to detect spoofing.**

measure the distance between the vehicles, with the accuracy dependent on the radar's resolution and its short distance performance. The camera and radar data would then be merged using sensor fusion, which may require raw source data and an extensive library of 3D image processing algorithms to combine and then extract the information. The maximum frame rate of such a system could be more than 3x slower than UWB frame rates. The simplicity of a UWB based system also reduces the probability that an issue with the code could cause an accident.

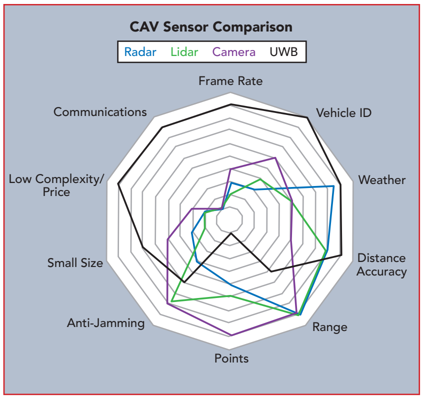
Figure 6 compares CAV sensors. The introduction of UWB into the CAV suite provides a robust, faster, secure and accurate system with superior price for the performance.

SUMMARY

Many of the techniques discussed in this article already exist. The 802.15.4z specification provides for a many-to-many UWB architecture, providing the basis for a secure multipoint ranging area network (RAN). V2V defines the ability for vehicles to form a group, which is the basis for selecting the vehicles to participate in the UWB many-to-many RAN. Once a group is formed, there is a need for specifications covering how the system using the V2V link can identify, select, initialize and operate a secure UWB RAN. For broad adoption, standards need to be developed to enable UWB devices on vehicles from different manufacturers to interoperate. Qorvo is leading an effort to have its patent-pending UWB + V2X concept adopted as a key part of the connected vehicle rollout.

UWB technology is a much simpler system than radar or cameras, requiring far fewer lines of code and less processing resources. With a low cost for implementation, centimeter accuracy and low latency, UWB provides a high performance to cost ratio, enabling manufacturers to implement a more robust CAV sensor suite.

Connected vehicles will introduce a new era of vehicle safety. The key to this will be the creation of a trustworthy communication environment between vehicles. UWB can provide the required trust between vehicles by ensuring they know each other's position, validating their identities. This is especially important when communicating life-critical information. High speed cooperative maneuvers are some of the most critical CAV operations. UWB can provide the speed and accuracy needed to enable the ANS to avoid life threatening situations by reacting much faster than a human, even faster than existing radar and camera systems. Even at slow speeds, vehicle maneuvering can result in fatal accidents, especially when a VRU is involved. By using UWB to measure the distance to VRUs, the navigation system can help ensure that accidents can be avoided. ■



▲ **Fig. 6** **CAV sensor comparison.**

Reference

1. Qorvo, "Ultra-Wideband for Dummies," www.qorvo.com/design-hub/ebooks/ultra-wideband-for-dummies.

DREAM ON

CEO Chris Marki Combines Creativity, Innovation and Hard Work to Deliver Performance Shattering Products in an Environment that Promotes Engineering Excellence

An Interview with CEO Chris Marki of Marki Microwave by JT Konstanturos

JTK: Please tell me how Marki Microwave came to be.

CM: My parents founded Marki in 1991, funded only by their own savings. It was an incredible risk, but my dad, as he tells the story today, "never had a doubt" we would succeed. My dad, who immigrated to the United States during the Hungarian Revolution, had become a world class mixer designer by this point in his career, so he was very confident that he would be able to deliver best in class performance… he was right. 30 years later, Marki Microwave still believes in dreaming big to solve the industry's toughest technical problems.

JTK: Can you tell me what is new in RF today?

CM: Actually, very little is new in RF anymore. Almost everything that we see today is a variation on a very old and well understood theme. This is not a criticism of our industry, but more of a recognition of the maturity of the field. RF technology dates to World War II when the British used radar to help with the Battle of Britain. Most of what you see in RF is a modern spin on an old concept. Marki Microwave is one such example. My father started in the field in 1971 and the technologies available to him during his career are fundamentally different than the ones we use today. But the physics are the same and the basic circuit concepts are identical. My dad is retired now, but whenever I show him a new idea or cool innovation, he instantly recognizes the underlying physics and novelty. Nothing is new—only repurposed and repackaged using modern manufacturing and technology.

JTK: When did you join the company?

CM: I joined in 2007. I had just completed a PhD in optics and realized that my dad had the best job in the world – invent stuff, build stuff and sell stuff. Coming out of grad school, that lifestyle was very appealing compared to constantly chasing research funding for questionably good ideas. My first goal was to not break anything and my second was to find new and better techniques to design and manufacture our products. We have had a good run of things and are about to move into a new factory that is six times bigger than the one I started at in 2007.

Your company states it is 100% Made in America. What does that mean to you?

CM: We aren't "Made in America" for any particular ideological reason. We are Made in America because that is how we can manage to build the best hardware in the world. Our designs and assembly techniques are highly differentiated and complex, and we carefully choose our suppliers and partners. *Nothing we do is a commodity*, so it is extremely rare to find something inside Marki that actually *could* be offshored. Beyond this, if you place your reputation on delivering best in class performance for your products, then it is important that the inventors and innovators on your technical team have close access to the people who actually build your parts. It would be impossible for me to innovate on many of our products if I had to fabricate the assembly in a distant country with a different time zone and language. The life blood of our technology is in the packaging, so it must be done domestically if we wish it to stay cutting edge.

JTK: What markets are your products designed for?

CM: I am big believer in bottom-up innovation and mostly ignore end markets. I believe that the most successful products require a "key technical insight", to steal a phrase I learned in the book *How Google Works*. My entire career in inventing and innovating products has involved ignoring specific markets or platforms and instead focusing on key technical challenges that face all our customers. This approach guarantees that we are always focused on cutting edge technology and not on wayward marketing projections. To do this, you must constantly antagonize your existing capabilities and search for new ideas to help solve hard problems.

JTK: Marki Microwave is investing in quantum computing, is that correct?

CM: Mainstream adoption of quantum computing is not an *if* but a *when*. It is truly changing the way we look at solving complex problems, but standardization is far off. Our interest in quantum is to understand how we fit into the ecosystem now and into the future, and then develop products and solutions that fit that particular space. I only recently began to appreciate that most of the big players in QC were already avid Marki customers, and many of the companies with headline grabbing announcements often use Marki hardware. My job is to listen to these incredible engineers and scientists, learn about their challenges, and position our product pipeline (to borrow a phrase from our company motto) "to shatter performance barriers."

JTK: How would you describe the Marki Microwave culture?

CM: Innovative and creative – both traits are in Marki Microwave's DNA. There is a strong artistic gene in my family. My father was a master jeweler and painter before he became an engineer. My mother was an outstanding violin player. I also have that creative instinct. When I was younger, I would watch in awe to see Stevie Ray Vaughan or Steve Vai play the guitar. They were doing things with six strings that felt magical. I have always wanted to "bottle lightening" like that, and I see a lot of similarities between the act of product design and the act of musical expression. It wouldn't surprise me if both of those came from the same part of the brain. I have always wanted to express my own technical ability through inventive and unique ideas, and in that way, I consider my designs to be like a new song or melody. The good news is that inventive creativity and the desire to write "unique music" is incredibly useful if you want to make differentiated technology. There is a reward in my field for people who can come up with clever solutions to problems, and a musical or artistic sense is correlated, in my opinion. Music is also central to my design practice. In fact, I associate certain bands and songs with specific Marki Microwave designs – I must have listened to Chris Cornell's final solo album 100 times while designing the circuits that eventually became the MM1-0626 mixer.

JTK: Are you hiring?

CM: You bet. We are looking for the best and the brightest talent who are not afraid to challenge the status quo. Some of the biggest advantages of working with a company our size is that we are small enough for you to have visibility and growth potential but large enough to provide the most up to date equipment and the expertise to support career growth. Most importantly, we have been around long enough to have earned an industry reputation for building cutting edge products you can't find anywhere else.

To view Marki Microwave's products and job openings, visit www.markimicrowave.com. For sales information, contact sales@markimicrowave.com or (408) 778-9952.

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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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MQ-4C Triton Completes First Flight in Multi-Intelligence Configuration

A Northrop Grumman Corporation-built MQ-4C Triton took to the skies for the first time in the highly upgraded multi-intelligence configuration known as integrated functional capability four (IFC-4). Triton is the U.S. Navy's premier high-altitude, long-endurance, maritime intelligence, surveillance and reconnaissance platform.

"The multi-intelligence configuration of Triton will completely revolutionize how the U.S. Navy and Royal Australian Air Force conduct maritime patrol and reconnaissance missions," said Doug Shaffer, vice president and program manager, Triton programs, Northrop Grumman. "Multi-intelligence capabilities, coupled with Triton's long-range sensors and 24-hour endurance, will enable an unprecedented amount of maritime situational awareness to inform real-time decision making at tactical to strategic levels."

Northrop Grumman is working closely with the Navy to progress Triton toward initial operating capability and world-wide deployments. The multi-intelligence configuration will also enable the Navy to retire the EP-3E Aries as Triton will be able to assume the intelligence collection missions currently conducted by the Aries.

"This hugely important milestone for our Triton Multi-INT program is the culmination of over five years of intense engineering, integration and test, and represents the efforts of the hundreds of team members who have worked so tirelessly to achieve this Herculean task," said Capt. Dan Mackin, Persistent Maritime Unmanned Aircraft Systems program manager.

The U.S. Navy is currently operating two Tritons in the Pacific region in the baseline configuration as part of an early operational capability deployment. The Triton program expects to achieve IOC in 2023 and the Navy will eventually maintain five 24/7 operational orbits with a planned 68-aircraft program of record.

MQ-4C (U.S. Navy Photo)

Nanosatellites Could Play Pivotal Role in Defense Against Enemy Missiles

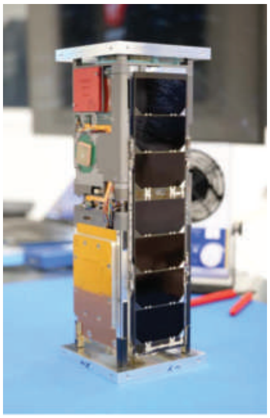
Two Missile Defense Agency (MDA) nanosatellites—known as CubeSats—that launched on June 30 into low earth orbit (LEO) from the Mojave Air and Space Port in California could play a large role in the future of U.S. missile defense.

The CubeSat Networked Communications Experiment Block 1—part of MDA's Nanosat Testbed Initiative (NTI)—uses small, low-cost satellites to demonstrate networked radio communications between nanosatellites while in orbit. MDA will conduct a 90-day demonstration, with a mission extension of up to one year, to ensure the two CubeSats can navigate properly, receive and send signals to radios and networks and operate as intended.

"These satellites will test key technologies that mitigate risk for systems, such as the Hypersonic and Ballistic Tracking Space Sensor," Walt Chai, MDA director for space sensors, said. "The CNCE Block 1 mission will demonstrate the viability of advanced communications technologies using reduced size, weight and power in support of missile defense communications architectures."

MDA is developing the Hypersonic and Ballistic Tracking Space Sensor payload. When eventually deployed on satellites in LEO, it will detect and track hypersonic and ballistic missile threats and provide critical data to the Missile Defense System and the warfighter. "The missile defense architecture will require communications between interceptors, sensors and command and control systems to quickly identify, track and destroy incoming enemy missiles before they reach their targets. The CubeSats will allow the agency to demonstrate the capabilities quickly and affordably," Chai said.

CubeSat missions allow for flexibility that includes rapid follow-on flights featuring planned, incremental technology improvements with overall greater cost efficiency than using larger, more traditional satellites.



CubeSat (Source: SDL)

According to Jeff Keller, chief engineer for technology maturation at MDA, a primary advantage to maturing technology through NTI is the ability to divide complex challenges into discrete parts. "This allows us to effectively balance risk and cost by utilizing a series of phased demonstrations. Each mission leverages lessons learned from the previous mission," he said. The overall result is that engineering and development of CubeSats is less costly than more highly customized small satellites. CubeSat payloads

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

also enjoy the cost benefits from commercial CubeSat technology, but they tend to be more specialized for the missions selected by the CubeSat user.

The CubeSats went to space aboard a VOX Space LLC, a subsidiary of Virgin Orbit, LauncherOne rocket as part of a payload-sharing arrangement with the DoD Space Test Program. Other agencies involved in CNCE Block 1's CubeSat development and experimentation are: defense department-led Mobile CubeSat Command and Control, ground station network, Space Dynamics laboratory (Mission Integrator), Space Micro Inc. (Payload) and Blue Canyon Technologies (Spacecraft Bus).

PAC-3 and F-35 Team Up to Defeat Threat in U.S. Army Flight Test

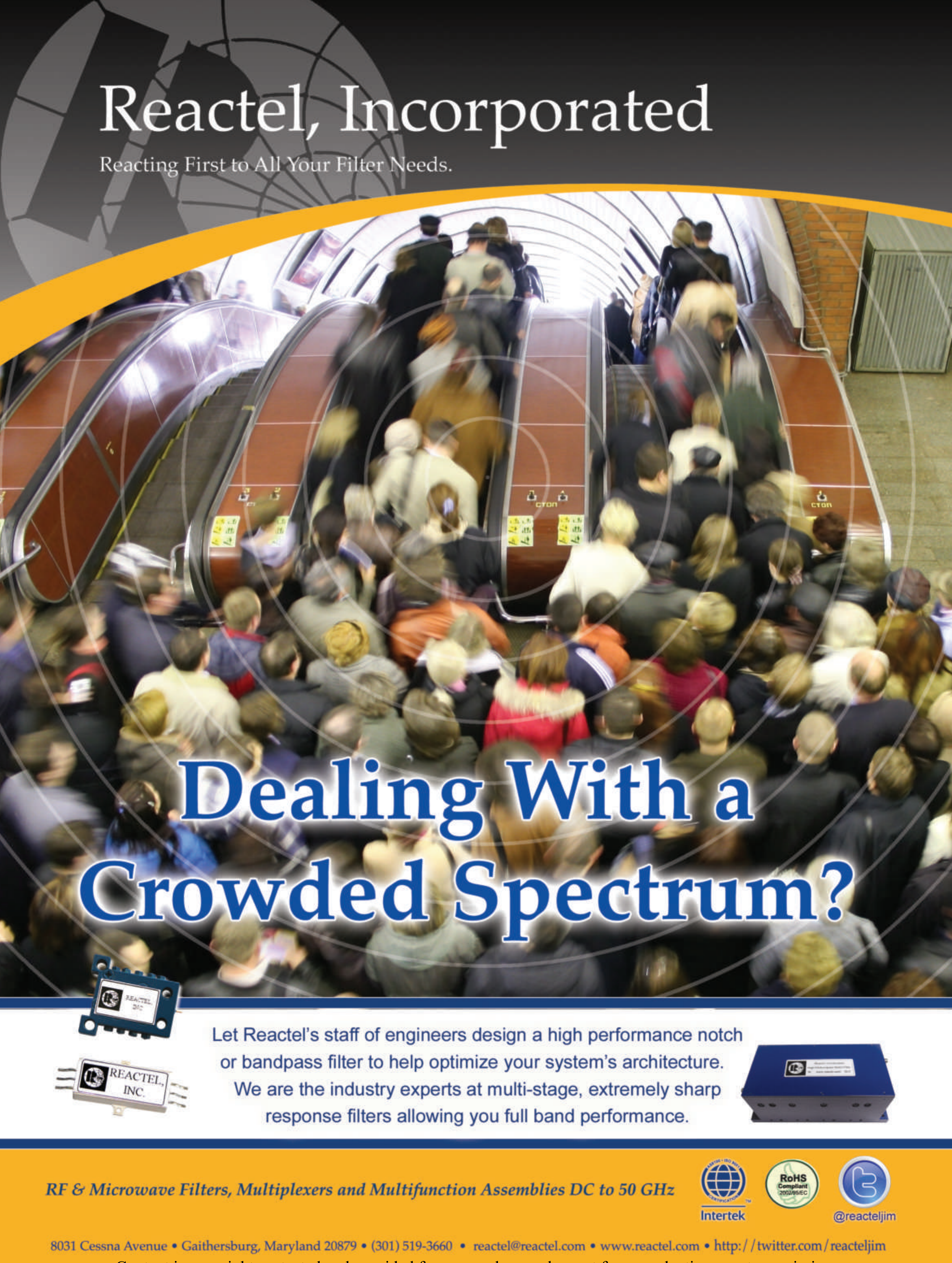
A Lockheed Martin PAC-3 missile successfully intercepted a surrogate cruise missile threat at White Sands Missile Range (WSMR), New Mexico, using an F-35 as an elevated sensor. The mid-July U.S. Army flight test marks a first in one flight test—F-35 data contributing to the global track used by the U.S. Army Integrated Air and Missile Defense Battle Command System (IBCS) to live fire a PAC-3.

IBCS, developed by Northrop Grumman, used the F-35 data with other contributing sensor data to initiate the launch of the PAC-3 to neutralize the incoming threat, using combat-proven Hit-to-Kill technology unique to the Lockheed Martin interceptor.

F-35 (U.S.A.F. Photo)

"Threats continue to evolve, and it's important that we always stay ahead of them. This flight test shows the impact of what we can do in Joint All Domain Operations when we use the U.S. Army's IBCS and airborne communications gateways to bring together the world's only combat-proven Hit-to-Kill interceptor with the world's most advanced fighter jet," said Brenda Davidson, vice president of PAC-3 Programs.

F-35 ISR track data was used with IBCS for the first time during OFE 19-2 to enhance situational awareness and provide weapons-quality track data to engage airborne targets with a virtual PAC-3. In December 2019, F-35s were used to provide track data to IBCS to successfully intercept near simultaneous air-breathing threats in a test at WSMR, New Mexico.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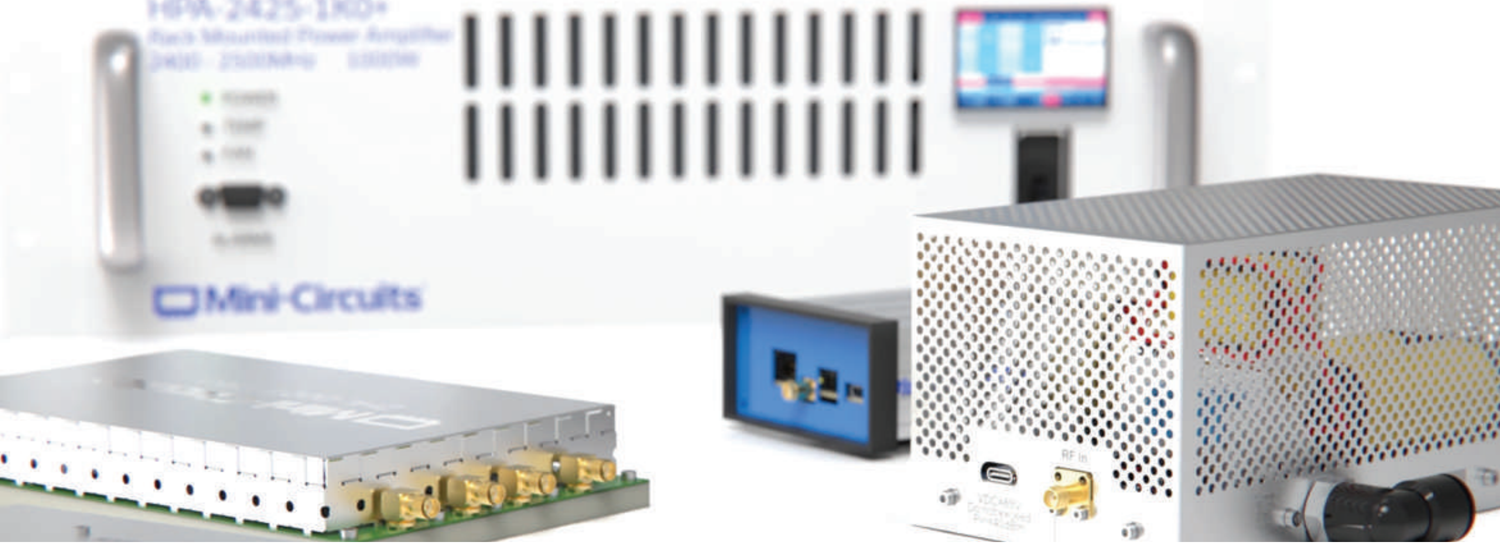

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Competition and Technology Complexity to Drive IoT Antenna Shipments

The growing breadth of IoT devices, machines and use cases combined with additional radio spectrum and protocols is creating more complexity in designing and integrating antennas into products. In a new application analysis report, "IoT Antennas: Technologies, Markets, and Evolution," ABI Research examines how the antenna market is evolving to address challenges specific to IoT and finds that growing competition and technology complexity will drive 7.2 billion IoT antenna shipments in 2025.

The report also highlights key technology trends, as well as shifting business models by antenna manufacturers and system-level approaches to RF design.

> "Increased radio complexity, device miniaturization, lower power consumption and a complex certification landscape are among many factors making integration of antennas more difficult..."

"Increased radio complexity, device miniaturization, lower power consumption and a complex certification landscape are among many factors making integration of antennas more difficult," said Tancred Taylor, IoT Hardware & Devices research analyst at ABI Research. "These challenges are well-known in the smartphone industry. However, unlike the smartphone market which comprises few OEMs and high product volumes, many OEMs in IoT do not have the in-house specialization to address this complexity and have a much broader range of products they want to create. This generates a large opportunity for antenna manufacturers to offer support and additional services throughout the project design cycle and offer value by moving beyond their traditional role as component manufacturers."

Vendors are changing their approaches to ensure they are addressing the unique needs of each device. In most cases, manufacturers such as Antenova or Ignion are building out their off-the-shelf product lines to complement or replace custom antenna offerings, helping smaller OEMs get devices to market faster, with less complexity and often with lower costs.

"While use case analysis indicates custom-designed antennas will remain the largest share of shipments, the shift toward offering a broader selection of prebuilt and tunable components could upset the dominance of custom antennas by making IoT device design and product assembly more accessible," Taylor explained. In a field where technology breakthroughs must clear constraints of physics, many antenna vendors are further turning toward software and services to deliver the best results. Approaches vary from offering design and simulation services or certification assistance, to helping an OEM throughout the design cycle of a product. Antenna manufacturers are looking to evolve their skills and capabilities by incrementally building out in-house expertise, as well as through acquisitions.

2021 Will be a Boon Year for 5G and Edge Networks Markets

The 5G edge networks value chain represents an opportunity for the industry to generate new revenue and gain visibility in a market that is set to include data center companies, enterprise end verticals, public cloud providers and content delivery network providers. All these players are investing significantly in edge locations, 5G infrastructure and the backbone networks that connect them. According to a new report from ABI Research, 5G edge networks will play a key role in unlocking the commercial potential of new use cases such as 5G private networks. In fact, ABI Research estimates that 5G private networks revenue is expected to grow from US$1.6 billion in 2021 to US$65 billion in 2030, with a compound annual growth rate (CAGR) of 60.1 percent.

"With 5G edge networks, every enterprise engagement is a custom job. Consequently, communications service providers (CSPs) and vendors seek to establish business models that are governed by different KPIs, both technical and commercial," explained Don Alusha, senior analyst, 5G Core & Edge Networks at ABI Research. This stands in contrast with product-led solutions that fit well with mass-market, country-specific/region-specific subscriber commercial models. 5G edge network deployments mark the first time that the industry focuses on business evolution and integration with vertical industries. To that end, tier-1 CSPs (e.g., AT&T, Telefonica, Verizon and Vodafone) and vendors (e.g., Ericsson and Nokia) are all establishing new enterprise business units.

Moreover, hyperscalers like Amazon, Google and Microsoft are taking a strategic approach with new solutions aimed at unlocking the value of 5G and edge networks. "CSPs own edge infrastructure that holds potential in terms of local compute and low latency connectivity, but they have limited cloud experience. Cloud providers are agile and innovative. With the right collaboration arrangements in place, there is no reason why 5G edge computing cannot yield value for all parties involved. At present, however, nobody can predict where this is going to go. It will be a captivating journey to see how different parties collaborate and

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co-create to unlock the value of the 5G edge networks being built today," said Alusha.

However, 5G edge networks face several key barriers that could impact market maturity. The business cases remain a key area where further work is required from the industry at large. The business case for advanced use cases depends on the market's appetite for 5G edge networks and enterprise's desire to modernize their operations. Furthermore, the technology ecosystem for edge computing is subject to ongoing maturity. It will take time to re-engineer existing hardware and software for highly distributed, space- and resource-constrained edge locations.

IoT Machine Learning and Artificial Intelligence Services to Reach US$3.6 Billion in Revenue in 2026

The next wave of IoT analytics development will fully converge with the Big Data domain. Simultaneously, the value in the technology stack is shifting beyond hardware and middleware to analytics and value-added services, such as machine learning (ML) and artificial intelligence (AI). According to ABI Research, ML and AI services are estimated to grow within the IoT domain at a CAGR of nearly 40 percent, reaching US$3.6 billion in 2026.

While COVID-19 impacted many industries, the IoT data analytics market has been less affected. In fact, many newly emerging cloud-native data-enabled analytics vendors have benefited from COVID-19. "Since industries are transitioning to 'remote everything,' out-of-the-box solutions for remote monitoring, asset management, asset visibility and predictive maintenance are in high demand and exemplify market acceleration. Vendors, such as DataRobot, are now easing access to ML and AI tool sets through different deployment options at the edge, on-premises and on the cloud and through consumption using platform as a service and software as a service," explained Kateryna Dubrova, research analyst at ABI Research. Companies like AWS, C3 and Google have also been successful in promoting their products and analytics capabilities by creating centralized repositories for COVID-19 data. Currently, these data lakes are public and are not monetized; however, it is expected that these companies will attempt to use the data lakes to create products for sale to the healthcare market in the future. From a technology perspective, the data lakes could be the first step for creating and testing data visibility and streaming analytics services. COVID-19 has showcased the public cloud's healthcare industry ambitions expanding into pharmaceutical, biomedicine and telemedicine.

Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Knowles Precision Devices has acquired Calif.-based **Integrated Microwave Corporation (IMC)**, helping to further expand its portfolio and better meet customer demands in the A&D markets. The acquisition of IMC enables the company to offer a complete range of RF and microwave filtering solutions—supporting VHF to Ka-Band—through the addition of ceramic, lumped-element and cavity filters for lower frequency and higher-power applications.

Skyworks Solutions Inc. announced that it has completed its acquisition of the **Infrastructure and Automotive** business of **Silicon Laboratories Inc.** in an all-cash asset transaction valued at $2.75 billion.

Facebook has sold its small-satellite internet division to **Amazon** and said it has no plans to become an internet service provider. Facebook asked the FCC for permission to launch a LEO satellite in 2018, but the company called it a small research and development experiment and did not publicly commit to offering internet service. Amazon plans a constellation of LEO satellites to compete against SpaceX's Starlink service, but Amazon's "Project Kuiper" is far behind the SpaceX venture.

Arlington Capital Partners, a Washington, DC-area private equity firm, announced that an affiliate has entered into definitive agreements to acquire **L3Harris Technologies' Electron Devices** and **Narda Microwave-West** divisions. The agreement is subject to customary closing conditions and regulatory approvals. After closing, the company will operate independently as Stellant Systems and will be a standalone platform for Arlington in the mission-critical defense electronics market. The transaction is occurring in partnership with current L3Harris Electron Devices' leadership, who upon close are expected to continue to operate and lead the company.

COMSovereign Holding Corp., a U.S.-based developer of 4G LTE advanced and 5G communication systems and solutions, announced that it has acquired **RF Engineering & Energy Resource (RFEQ)**, a specialist in the design, outsourced manufacturing and distribution of ultra-high performance microwave antennas and other branded solutions for the wireless and wireline industries in the U.S. and Latin America. Terms of the transaction include total consideration of approximately $2.2 million worth of shares of restricted common stock and $550,000 in cash.

Qualcomm Inc. said recently it had offered to buy Swedish auto parts maker **Veoneer Inc.** for $4.6 billion, an 18.4 percent premium to a bid in July by Canada's **Magna International Inc.** that was accepted by Veoneer's board. U.S.-listed shares of Veoneer, spun off in 2018 from air bag and seatbelt maker Autoliv, rose 28 percent as the stage was set for a bidding war. Autoliv had previously acquired MACOM's automotive radar product line. Veoneer said its board of directors would "evaluate the proposal from Qualcomm consistent with its legal duties and the terms of the Magna merger agreement." Magna did not make any immediate comment.

COLLABORATIONS

Cellular-V2X is a key technology that will improve road safety and accelerate autonomous driving in the coming years. Specifically, the C-V2X PC5 interface, operating in the 5.9 GHz frequency enables direct, reliable, low latency communication between vehicles (V2V), vehicle-to-infrastructure (V2I) and vehicle-to-pedestrians (V2P). In order for the automotive industry to deploy this technology in a timely manner, cooperation between suppliers in this industry becomes increasingly important. The test cases performed by **Rohde & Schwarz** and **Quectel** are ideal for automotive companies looking to pre-validate 3GPP system performance in an automated and timely manner before entering OMNIAIR or CATARC certification process.

Pivotal Commware Inc. and **CommAgility** have announced the integration of CommAgility's physical layer software into Pivotal's Echo 5G and Pivot 5G repeaters designed for delivering superior broadband experiences to more 5G mmWave subscribers at lower costs. Echo is a low-profile, glass-attached repeater installed by subscribers to facilitate in-building penetration of mmWave signals from 5G small cells. The Pivot outdoor network repeater extends mmWave signals beyond the base station's line-of-sight so carriers can increase coverage for less cost.

SES and **QuadSAT** have jointly performed a ground segment satcom antenna validation campaign. Using QuadSAT's revolutionary new drone technology, this mission redefines the possibilities for antenna diagnostics within the framework of Industry 4.0. By obtaining accurate antenna performance data from anywhere in the world from original equipment manufacturers, SES was able to quickly validate new antenna models to be added to their satellite networks, mitigating the risk of generating interference on their own satellite or adjacent satellites.

SiTune and **MixComm** announced a collaboration to develop 5G mmWave reference designs. These solutions will be based on SiTune's IceWings RF transceiver and MixComm's mmWave solutions including the SUMMIT2629 Beamformer Front End IC and the ECLIPSE3741 Antenna in Package, which was recently released. Both SiTune and MixComm have been recognized for developing high performance yet energy efficient 5G solutions. Through this collaboration, customers will be able

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to develop systems that maximize performance and thermal efficiency but with an optimal bill of materials and fast time to market.

Teledyne e2v HiRel Electronics announced that it will be offering high reliability qualified versions of Calif.-based **Integra Technologies Inc.'s** new 100 V GaN/SiC power transistors. Integra's newly announced 100 V RF GaN/SiC gives designers the ability to dramatically increase system power levels and functionality while simplifying system architectures with less power combining circuitry compared to the more commonplace 50 and 65 V GaN technologies. Teledyne will qualify Integra's first 100 V product, the IGN1011S3600, which offers 3.6 kW at 1030 to 1090 MHz, greater than 19 dB of gain and up to 75 percent efficiency.

NEW STARTS

Gowanda Electronics announced the launch of its new brand identity with a redesigned logo and new website. The rebrand solidifies the company's leadership position in engineered components for the global electronics marketplace. The new Gowanda logo has a look and feel that aligns with the company's premier supplier status which is rooted in nearly six decades of inductor design and production expertise combined with close working relationships with its customers. The rebranded website offers an advanced parametric search tool, easy-to-navigate pages and a structured layout for a simplified user experience.

ACHIEVEMENTS

BAE Systems Inc. announced a strategic business agreement that will result in the BAE Systems' FAST Labs™ research and development organization having early access to select Intel technologies. The agreement will enable BAE Systems to develop and more quickly field next-generation defense applications based on Intel's most advanced technology. While commercial off-the-shelf semiconductor technology has increasingly been incorporated into U.S. defense applications, military-grade technology requires domestically developed custom capabilities that go beyond commercially available technology.

Keysight Technologies Inc. announced that **vivo** selected the company's 5G channel emulation solutions to perform complex 5G device testing. Keysight's PROPSIM F64 RF Channel Emulator, part of the company's portfolio of channel emulation solutions, was chosen by vivo to perform MIMO over-the-air (OTA) testing in a laboratory environment under a diverse range of real-world mobility scenarios.

Raytheon Missiles & Defense successfully defeated a swarm of drones with its reusable Coyote® Block 3 non-kinetic effector during a U.S. Army test. The demonstration moves the variant closer to deployment. Derived from the expendable Coyote loitering munition, the Block 3 utilizes a non-kinetic warhead to neutralize enemy drones, reduc-

ing potential collateral damage. Unlike its expendable counterpart, the non-kinetic variant can be recovered, refurbished and reused without leaving the battlefield.

CONTRACTS

Ericsson announced a landmark multi-year agreement with **Verizon** to provide its industry-leading 5G solutions to accelerate the deployment of Verizon's world-class next-generation 5G network in the U.S. Under this USD $8.3 billion agreement, Verizon will deploy Ericsson's 5G MIMO C-Band, low-band and mmWave solutions to enhance and expand Verizon's 5G ultra-wideband (UWB) coverage, network performance and user experience.

Kymeta announced it has been awarded a $950,000,000 ceiling indefinite-delivery/indefinite-quantity contract for the maturation, demonstration and proliferation of capability across platforms and domains, leveraging open systems design, modern software and algorithm development in order to enable Joint All Domain Command and Control.

Comtech Telecommunications Corp. announced that during its third quarter of fiscal 2021, its Santa Clara, Calif.-based subsidiary, **Comtech Xicom Technology Inc.**, was awarded a follow-on order valued at more than $1.0 million for its Falcon 50Ka Solid-State Power Amplifiers for an in-flight connectivity application. These amplifiers feature a tri-band block up-converter and are packaged in ARINC 791 compliant housings.

CAES has been awarded multiple contracts to provide RF and microwave rotary joints and waveguide products for an advanced U.S. missile defense program. CAES rotary joints and waveguides will be integrated into the system's missile seeker, providing industry-leading performance and reliability. Used extensively in government and industry applications for over 50 years, CAES has produced thousands of designs for rotary joints which provide the vital link between the stationary and movable parts of a missile seeker, with little to no distortion.

Epiq Solutions has won a Phase II **Department of Homeland Security (DHS)** contract to develop a simple, seamless, low size, weight and power in-building coverage analysis system to aid first responders. As part of the DHS Small Business Innovation Research (SBIR) Program, DHS is seeking a solution for the critical problem of achieving reliable emergency communications network coverage in buildings of various types at different locations.

STAR Dynamics Corp. announced it has been awarded a significant contract with the **United States Air Force (USAF)** National RCS Test Facility (NRTF) to design, develop and manufacture an UWB signature measurement system (SMS) as a component of the NRTF Dynamic Radar Cross Section Measurement System (DRMS). The SMS will be capable of both radar cross section mea-

surements and inverse synthetic aperture radar imaging measurements to validate the radar signature integrity of low observable aircraft in dynamic, full-flight operational configurations from a ground-based DRMS/SMS facility.

PEOPLE

▲ *David Lynch*

▲ *Dane Ramkalawan*

APITech has announced three new leadership appointments to its Delmar facility, which produces high performance filter products and integrated microwave assemblies. **David Lynch Ph.D.** has been hired as the senior director of RF2M-US Engineering. Lynch previously served as the chief technology officer at Filtronic PLC, where he led a global team of engineers in charge of technology and product strategy. **Tracy McKenrick** has been hired as the Delmar facility's quality manager. McKenrick last served as quality manager at Jacquet Mid-Atlantic, where he was responsible for upgrading and maintaining their ISO-9000 and AS9100 certifications. **Dane Ramkalawan** is the Delmar facility's new site leader. Ramkalawan served for more than five years at Micross Components as vice president of operations.

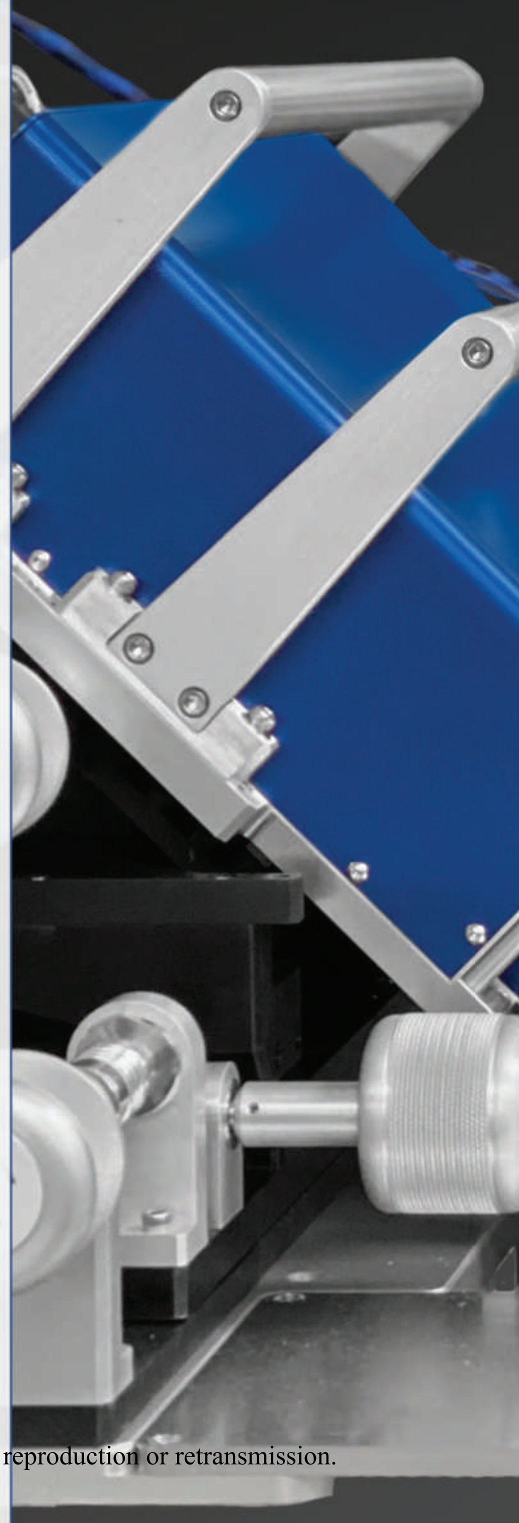
REP APPOINTMENTS

Beginning in June 2021, **Ohmite Manufacturing Company Inc.** and its acquired partner, **ARCOL,** have signed with Europe-based **Power Rep**, a commercial company focused on industrial electronics, to expand Ohmite/ARCOL's presence in Europe. Power Rep will be coordinating all of Ohmite/ARCOL's distribution, sales and support in Italy, Turkey, Malta and Greece in an effort to increase the company's profile in those territories.

PLACES

GlobalFoundries announced expansion plans for its most advanced manufacturing facility in upstate New York over the coming years. These plans include immediate investments to address the global chip shortage at its existing Fab 8 facility as well as construction of a new fab on the same campus that will double the site's capacity.

Pixus Technologies announced the launch of Pixus Technologies USA Corp. with an office opening near Buffalo, N.Y. The company has also joined the Sensor Open Standard Architecture (SOSA) Consortium. Canadian-based Pixus Technologies Inc. has been providing ruggedized and commercial OpenVPX and other COTS backplane/enclosure solutions for over ten years.

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INVITED PAPER

Early Indications of 6G

Charles Schroeder
NI, Austin, Texas

THE EVOLUTION OF CELLULAR TECHNOLOGIES

While 5G deployments are just rolling out, those on the forefront of wireless communications research and standards are already looking toward 6G. Thought leaders from industry and academia are starting to define the vision for 6G and identify target use cases and promising technologies. While lofty goals motivate innovation, early research is critical to begin testing and proving what is achievable. Over the next few years, as many of us start to see 5G technology appear in our daily lives, 6G will be taking shape, first through pre-standards consortia and conferences, then through the 3GPP standardization process.

Over the past 40 years, cellular technology evolution has yielded a new generation of wireless standards approximately every decade and a transformative value proposition every 20 years. 1G and 2G targeted voice, bringing a new level of mobility and reachability to users. 3G and 4G tackled data, delivering the power of the internet, email and apps to handheld devices. Similarly, we expect that the effort and advances of both 5G and 6G will be needed to realize the wireless interconnection of everyone and everything.

5G's initial release targets the most familiar usage scenario for consumers: enhanced mobile broadband to provide higher data rates for more users to tether or stream video to their phone on the go. The other 5G usage scenarios of massive machine-type communications (mMTC) and ultra-reliable low latency communications (URLLC) will get a boost with follow-on enhancements to enable use cases like industrial IoT and private networks driven by business applications. While these are certainly important technological advances, they have not yet reached the point of transforming peoples' everyday lives.

WHAT 6G MIGHT LOOK LIKE

So, what's next? What comes after voice calls and the internet? The aim of 5G is sometimes summarized as "connected everything"—connecting billions of devices across vastly different usage scenarios embedded into all aspects of our lives. 6G extends the vision beyond just connections, integrating sensing to deliver truly immersive experiences (see ***Figure 1***). While humans initiated the majority of wireless connections in 1G through 4G to make calls or get information, in 5G and 6G machines will be increasingly initiating these connections as they self-coordinate on our behalf. Terms like tactile internet and wireless cognition may sound like science fiction, but that may not be the case for much longer.

While highly publicized steps are already bringing us closer to autonomous vehicles, other areas like eHealth and remote surgery, spectroscopy and imaging and centimeter localization to pinpoint a device's physical position are only just starting to be explored. In addition, the ability to sense the sur-

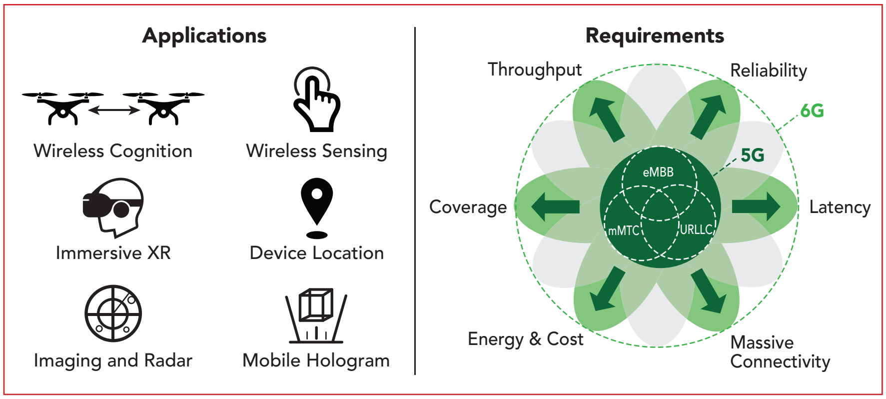

Fig. 1 6G applications will require 5G network capabilities to be significantly enhanced.

rounding environment also offers powerful new ways to optimize the network, based on physical position, proximity or other factors, to improve performance and efficiency. Some of these use cases may sound familiar and, in truth, many of them have existed as concepts since the early days of 5G. But the advances of 6G will be needed to make them a reality.

PROMISING ENABLING TECHNOLOGIES

To deliver on this ambitious vision, NI sees four key technology areas gaining broad interest in 6G research:

- Use of higher (sub-THz) frequencies
- Evolving multi-antenna techniques
- Adoption of artificial intelligence (AI) and machine learning (ML)
- Integration of communications with sensing capabilities.

Combining these technologies offers the potential for faster, higher capacity networks, the latency and sensing capability to enable rich, real-time experiences and the intelligence to optimize for numerous applications and key performance indicators (KPIs).

Moving to higher frequencies has already presented plenty of challenges in 5G mmWave, but the allure of wide swaths of unused sub-THz spectrum is irresistible. While the applications and business cases remain somewhat fuzzy, researchers are working to understand propagation characteristics and determine technical feasibility. A paper published by NYU Wireless researchers paints a surprisingly optimistic view of the potential of sub-THz frequencies for applications in outdoor urban environments, as well as backhaul and non-terrestrial networks. Data from initial channel sounding experiments at 142 GHz show that high propagation loss in the first meter of propagation and diffraction commonly thought to be prominent detractors for non-line-of-sight operation at these frequencies may be mitigated by high gain antennas and stronger reflections from common materials like glass and concrete walls.[1]

Large antenna arrays with many elements and more precisely directed beams are needed to overcome higher path loss and make sub-THz frequencies usable. In lower frequency bands, enhancements to massive MIMO are being considered to increase cell capacity. One new approach is distributed MIMO, which uses multiple geographically separated radio heads across the cell to improve performance. Given that the sub-6 GHz frequency bands serve most users today, even incremental spectral efficiency gains are extremely valuable.

As we've already touched on, the concept of joint communications and sensing is vast, spanning many industries, applications and device types. Different aspects of sensing—including object detection, analysis of material properties, localization and gesture recognition—are being looked at from both a use case and technology perspective. The Barkhausen Institute is conducting research on joint communications and radar sensing techniques that may benefit several applications, such as Industry

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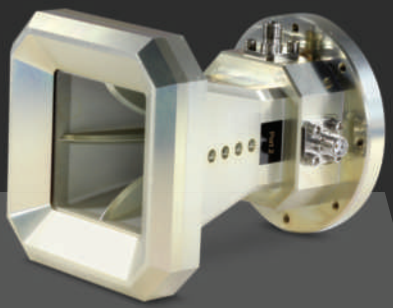

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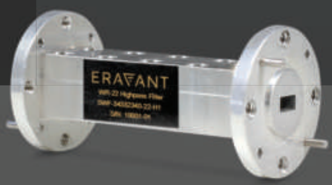

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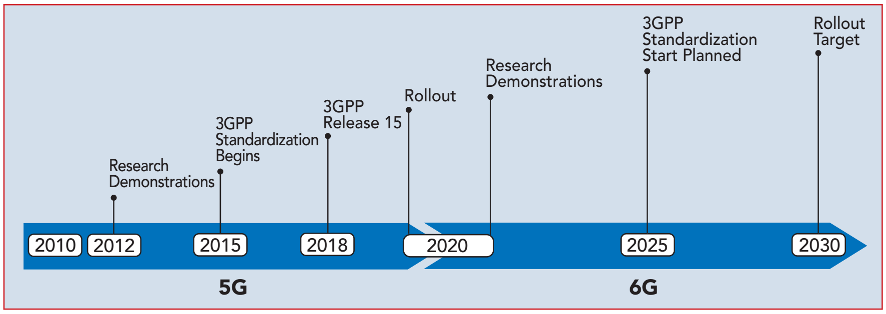

Fig. 2 6G research occurring in parallel with 5G advancements, with 6G standards beginning by 2025.

4.0, autonomous driving and, more generally, "radar as a service." These techniques could, for example, solve radar coordination issues and make beam alignment easier for mmWave communications at the same time. In several published papers, Barkhausen researchers explore the use of a chirped waveform that may be capable of serving both radar and communications, enabled by a single, reconfigurable, co-designed hardware system implementation.[2,3] Historically, the primary goal has been the coexistence of radar and communications, but combining them to use the same waveform, spectrum and hardware could enable more flexible, efficient use of resources.

AI and ML will be another key enabler to squeeze every bit of bandwidth out of the available spectrum and optimize the network's performance. On the RF side, examples include dynamically allocating resources, improving beam management and correcting for RF chain impairments or channel effects. At the application layer, with such a diverse set of use cases, AI and ML could help optimize for application-specific KPIs and make trade-offs between metrics like throughput, latency or energy efficiency. The availability of data is a prerequisite for AI and ML design and adaptation. Large, open datasets to train algorithms are essential for research and development, and additional sensing and data collection will be needed to drive AI-enabled decisions when deployed. Perhaps even more exciting than the wide-ranging possibilities for improving network performance, AI and ML have enormous potential of enabling a vast set of new applications built on top of 6G networks and devices.

While the viability and, ultimately, the value of these technologies remain to be proven, these early explorations provide a window into an exciting new frontier for commercial wireless communications.

CONCLUSION

The first 6G study items are expected to appear in 2025, kicking off the standardization work toward a 2030 rollout, while the evolution of 5G will continue in parallel with early 6G research (see ***Figure 2***). The transformative value that we hope 5G and 6G will deliver is fun to imagine and, inevitably, there will be significant challenges encountered along the way. The data and learnings from these early research efforts are critical inputs for the broader wireless ecosystem to gain consensus on the technologies and use cases around which to build the next generation standard. ■

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5G


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Addressing EMC Challenges in Electric Vehicle Supply Equipment

Hwee Yng Yeo
Keysight Technologies, Santa Rosa, Calif.

Globally, electric vehicle supply equipment (EVSE) has doubled in the past three years. The last count in 2020 showed 1.4 million[1] charging points across the globe. This market is set to cross $14 billion in 2026, a compound annual growth rate of 36 percent over the next five years. This momentum is fueled by growing demands in various markets, underpinned by incentives for car buyers to switch to electric transportation and policies driving zero emission goals.

In the U.S., which trails China and Europe in electric vehicle (EV) adoption, the Biden administration unveiled the Bipartisan Infrastructure Framework[2] in June to help automakers boost production of EVs. Plans include a boost of $7.5 billion for public charging infrastructure, with the goal of adding 500,000 EV chargers by 2030. At the consumer end of this complex e-mobility ecosystem, electric car drivers expect to drive up to any charging point to charge their batteries as easily as they can fill their gas tanks in current combustion engine cars.

EVSE suppliers certainly have this impetus to ride the global time-to-market wave, requiring some new technology challenges to be tackled: safety, performance and interoperability among electric cars and the charging stations. With expectations of faster and higher power charging comes the need to ensure safety and performance, across an increasing range of car models and EVSE vendors. A key area is ensuring electromagnetic compatibility (EMC) of the EVSE, with the vehicles they will charge and the plethora of electronic devices that rule modern life. With more charging stations sprouting across cities, especially near residential areas and schools, EMC standards


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are evolving to protect both the public and industry. For EVSE makers, ensuring their products comply with these standards supports product safety, performance and reliability—at the same time building market confidence and brand reputation.

Before discussing the implications of electromagnetic interference (EMI) in the EV charging environment and why EMC conformance testing is so important, let's define two common acronyms:

- EMI: electromagnetic disturbances that degrade the performance of electronic or electrical equipment
- EMC: the capability of electrical and electronic systems and devices to operate in their intended electromagnetic environment without unacceptable degradation from electromagnetic interference.

WHY IS EMC TESTING SO IMPORTANT?

A charging station can produce radiated emissions caused by electromagnetic waves radiated into space while the charging station is being used. It can also produce conducted emissions from the voltage and current in the power cable. This EMI can potentially disrupt the proper functioning of other electromechanical devices and wireless communications and may pose health risks to people. With the convergence of connected autonomous driving technology and electric cars, it is vital that the EVSE is tested to identify and correct any interference with the onboard safety and communication systems.

In an interesting study,[3] researchers from the Technical University of Munich (TUM) measured the electromagnetic fields of EV and EVSE and the impact on pacemakers inside cardiac patients. The largest electromagnetic field detected was along the charging cable during high current charging: 116.5 µT. The field strength in the EV cabin was lower: 2.1 to 3.6 µT. Fortunately, the research found no change in the functioning of the pacemakers; however, with both EV and EVSE technology constantly advancing, the TUM researchers advised caution for these patients when outside the car, for instance during charging around Level-2 (240 V) and Level-3 (400 V) charging stations, which use high electric current.

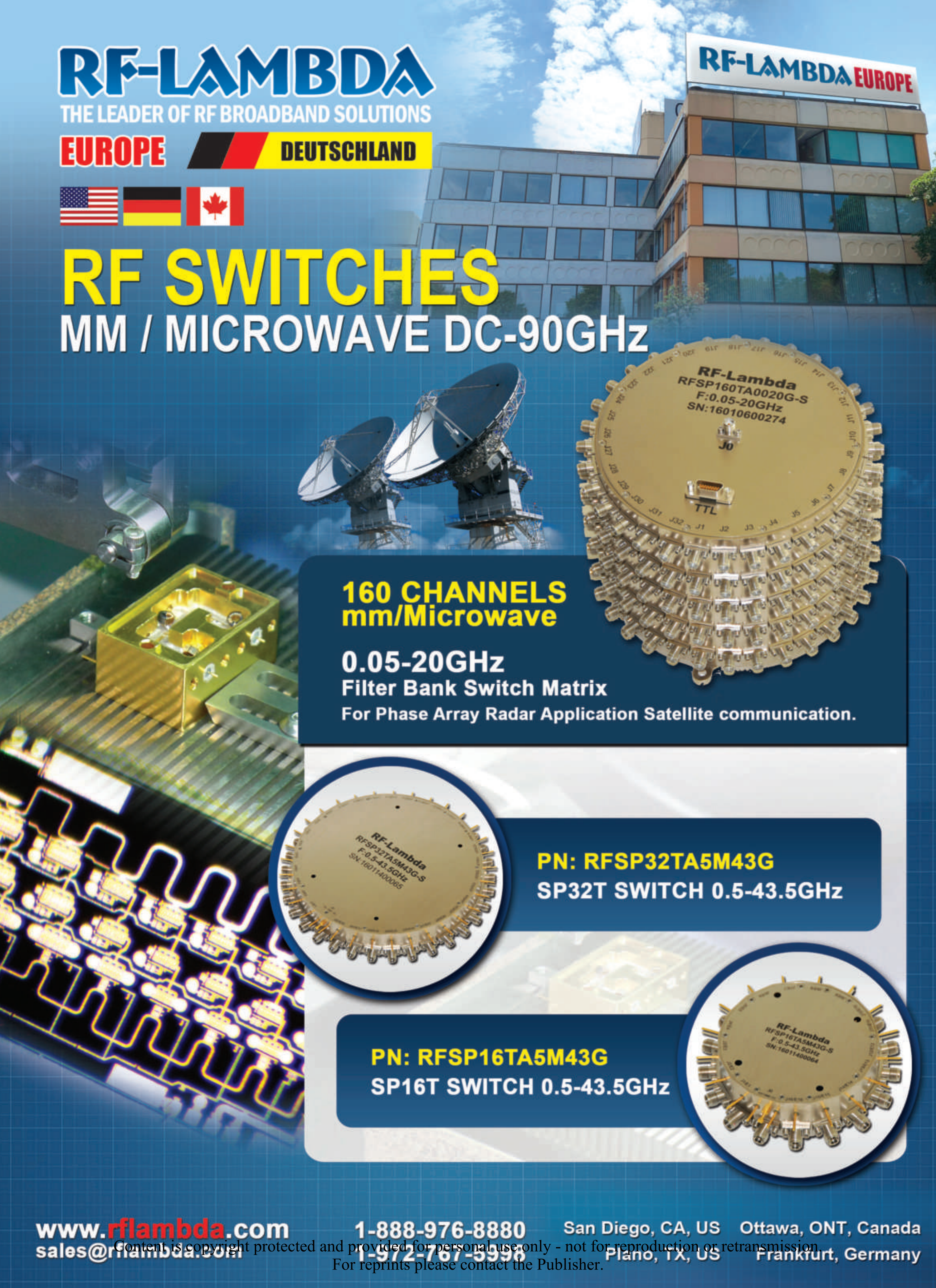
MULTIPLE EMC STANDARDS

EVSE manufacturers must meet several EMC regulatory requirements and certifications before releasing products to market. For instance, the European IEC 61000 EMC standard defines limits to provide reasonable protection against harmful interference. This is the directive that addresses EMI issues for EV charging infrastructure products. In the U.S., EMC compliance is regulated by the Federal Communications Commission. Class A limits cover commercial, business and industrial environments, while Class B, the more stringent category, covers EVSE in residential areas (see ***Table 1***). In Canada, the ICES-003, Section 5 standards require EV charging station providers operating in areas with exposure to the public to have Class B compliance. If a charging station does not have Class B certification, it must display a warning label to caution users that magnetic fields around it can be problematic. This does not bode well if an EVSE supplier aims to gain market confidence.

Other key charging and EMC

TABLE 1
FCC EMC COMPLIANCE LIMITS
Source: LearnEMC[4]

Frequency of Emission (MHz)	Field Strength Limit (dBµV/m)
Class A 10 m Radiated EMI Limit	
30 - 88	39
88 - 216	43.5
216 - 960	46.5
> 960	49.5
Class B 3 m Radiated EMI Limit	
Frequency of Emission (MHz)	***Field Strength Limit (dBµV/m)***
30 - 88	40
88 - 216	43.5
216 - 960	46
> 960	54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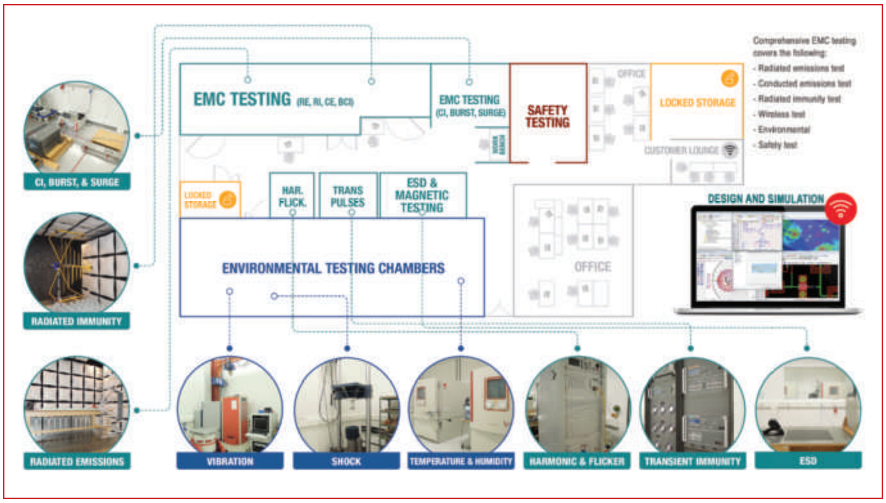

Fig. 1 Capabilities of an EMC test lab. *Source:* Keysight EMC Test Lab.[5]

norms and standards include the following:

- **IEC 61851-21** – This is an EMC product standard that specifies the limits of emission and immunity (i.e., the minimum test levels) for electric road vehicle charging systems.
- **IEC/CISPR 11, EN 55011** – This standard covers emission requirements related to RF disturbances in the frequency range from 9 kHz to 400 GHz.
- **TL 81000** – This covers the EMC requirements for electronic components in motor vehicles.

MEASURING EMC COMPLIANCE

Ensuring EVSE meets safety and performance requirements requires having comprehensive compliance test processes and reliable test and measurement equipment. These are the essentials to measure the causes and impact of electrical noise, enabling engineers to define, debug and circumvent EMI causes and effects. In addition to EVSE circuitry, user interfaces such as touch screens, displays and wireless communication interfaces, such as those used for contactless payment, must be thoroughly tested against both conducted and radiated emissions. To meet these evolving conformance standards and regulations, EVSE manufacturers must plan test capacity and the capability to handle increasing test complexity while planning their design, development and production cycles (see ***Figure 1***).

In today's competitive e-mobility market, EVSE manufacturers must adapt quickly to test a wide range of EVs to ensure their charging products conform to the necessary standards, which differ around the world. In many cases, the EVSE manufacturer does not have access to detailed information about how the EV manufacturer has implemented its controller or if it complies with the published standards. For this reason, a holistic compliance test requires a "synthetic" setup which emulates the real-world environment of a charging station, operates within the appropriate specifications and provides appropriate means of defect detection and analysis. This real-world emulation test environment provides further advantages:

- A real electric car is not needed in the test lab. The emulator simulates the specifications of different EV models.
- The charging duration is not restricted, as an electronic load is used instead of a battery with limited capacity.
- Tests can be fully automated, which is particularly useful with recurring test sequences and large numbers of units, such as with end-of-line testing.

A key consideration for EMC testing in this emulated environment is whether the test equipment itself is properly shielded so it provides "unbiased" measurements necessary for EMC compli-

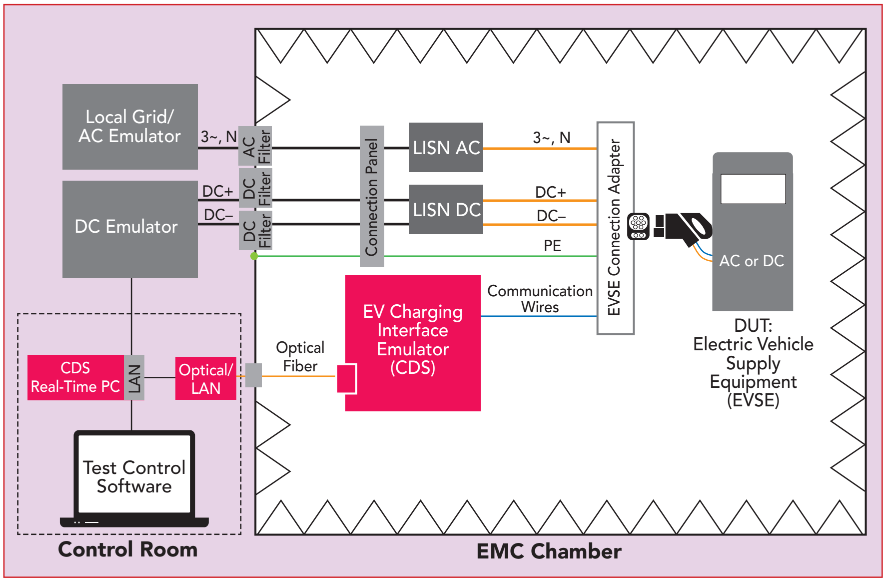

Fig. 2 Test setup for EMC testing of the EVSE. *Source:* Keysight Scienlab CDS.[6]

ance and homologation tests.

The EMC test architecture illustrated in ***Figure 2*** shows an EMC-optimized emulator, the Keysight Scienlab Charging Discovery System (CDS), which is configured in this use case to act as an electric car for testing EVSE. Both the emulator and the EVSE device under test (DUT) are inside an anechoic chamber for the EMC immunity and emission tests of EV charging infrastructure, such as DC fast-charging stations or AC or DC charging.

Due to the special EMC shielded design and built-in low noise components, emission from the emulator is reduced to a minimum. This enables EMC testing of EVSE under real charging conditions without environmental interferences. Since the emulator is immune to external electromagnetic fields, it can be placed close to the EVSE DUT during immunity testing.

OUTLOOK

Demand for EMC testing is likely to grow in the coming years, buoyed by market drivers such as faster and higher power charging and the convergence of connected automated driving features on the e-mobility platform. While new conformance standards and regulations may pose challenges for EVSE manufacturers, they have opened opportunities for companies offering EMC testing and certification services. This collaborative approach is a win-win for the industry, allowing EVSE manufacturers to focus on developing and deploying a safe, reliable charging infrastructure as part of building a zero carbon footprint transportation future. ■

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INVITED PAPER

Modern Flat Panel Antenna Technology for Ku-/Ka-Band User Terminals in LEO Satellite Communications Systems

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In recent years, an increasing number of broadband satellite systems have been launched into low earth orbit (LEO), connecting people across the globe. Flat panel antennas are especially attractive for LEO satellites due to their tracking ability, low profile and easy installation. This article discusses three major antenna technologies: electronically scanned array (ESA), variable inclination continuous transverse stub (VICTS) and lens antenna. ESAs consist of arrays of individually controlled radiating antenna elements with different phase delays that coherently form and scan the antenna beam in the far field. Within the category of ESA antennas are analog, digital and hybrid antennas with passive or active radios. VICTS antennas consist of rotating disks that steer the beam and change polarization based on the relative position of the disks. Lens antennas consist of modular lens sets that steer the beam by individually controlling the source of energy relative to the focus of each lens. Each of these technologies has strengths and weaknesses that are compared in this article using the size, weight, power consumption and cost (SWaP-C) metric.

Since 2015, numerous satellite communications companies have designed and launched high throughput broadband systems to connect rural and underserved markets. These satellite systems have become more technologically feasible than those two decades ago, due to advances in wireless technologies as well as decreases in launch service and manufacturing costs. Non-cost prohibitive user terminals (UTs) and service plans, however, are required for a profitable broadband business, particularly in rural areas.

Ku- and Ka-Band satellite UTs require highly directive antennas to close RF links with satellites orbiting at altitudes of a few hundred to a few thousand kilometers above the earth's surface. Fixed parabolic reflectors are commonly used for conventional geostationary (GEO) satellite systems, which do not necessitate tracking, as the satellite's position relative to the user terminal is fixed over time. LEO constellations, however, require tracking and satellite-to-satellite handovers to maintain connectivity. These features, along with cumbersome mechanics and form factors, make parabolic antennas less attractive for LEO systems.

Flat panel antennas with low profiles and user-friendly installation processes have therefore become critical components in successful satellite broadband systems. This article discusses current Ku-/Ka-Band UT antenna technologies, describing ESA, VICTS and lens antenna architectures. It discusses advantages and disadvantages in terms of SWaP-C.

ESA ANTENNA

For LEO systems, an attractive alternative to the conventional dish antenna is an ESA, also known as a phased array antenna. An ESA includes an array of several individual sub-wavelength radiating antenna elements whose relative phases are controlled such that the overall beam from the array radiates in a particular direction due to constructive and destructive interference between individual elements.[1] The process of constructing a concentrated beam using phased array antennas is called beamforming.[2] The strength of the overall beam depends directly on the number of coherent radiating elements and the array configuration in the antenna; a higher number of radiating elements contributes to a narrower and more powerful main lobe with smaller and less powerful side lobes (see ***Figure 1***).

Beamforming antenna systems can actively position their main beams and their nulls at specific angular locations using either analog phase shifters or digital coding algorithms. These beam steering techniques increase the throughput of the phased array without increasing transmit power.[3]

Three popular beamforming techniques are analog, digital and hybrid. While all three have have similar high-level architectures, there are two types of hardware implementations. Any of these beamforming techniques can be implemented using active radio components (e.g. RF amplifiers) external to the array or using integrated electronics (where the radios are embedded directly into the antenna array). A beamforming architecture with RF amplifiers built into the antenna array is called an active beamforming array. Beamforming architectures with external amplifiers or radios are called passive beamforming arrays.[4]

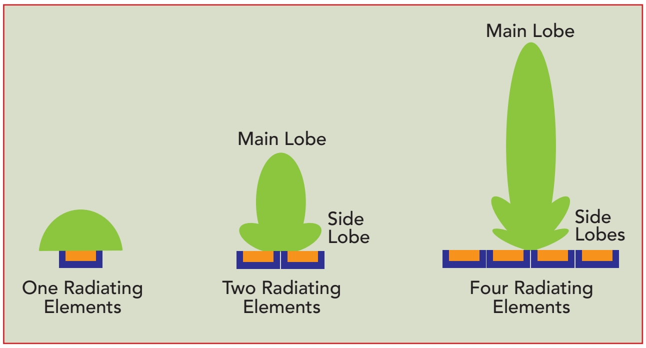

Fig. 1 **Antenna array gain and beamwidth depend on the number of radiating elements.**

Active Beamforming

Analog beamforming is the most basic technique. It uses a single RF chain that connects each antenna element with amplifiers and phase shifters followed by splitters or combiners (see ***Figure 2a***). The phase shifters, splitters and combiners are implemented using

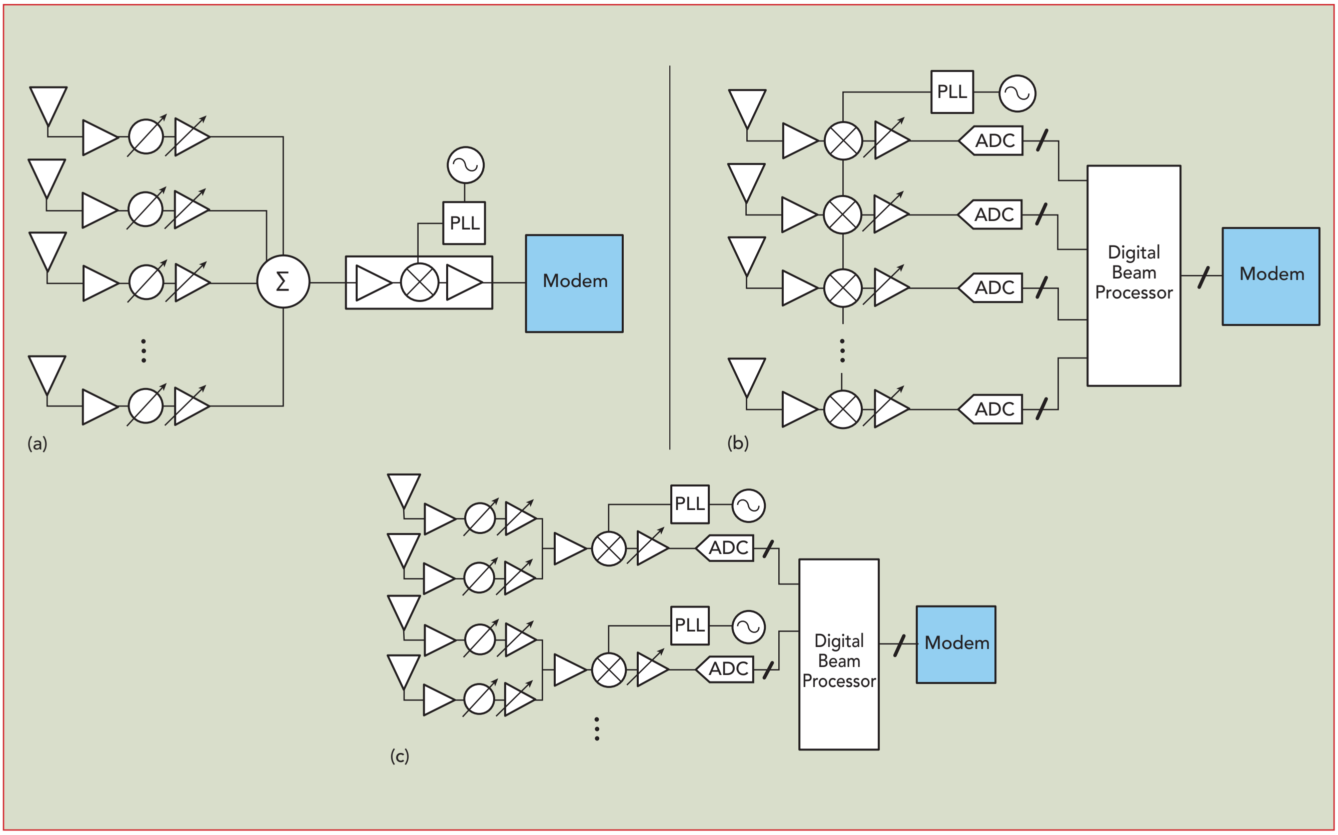

Fig. 2 Receiver architectures for analog beamforming (a), digital beamforming (b) and hybrid beamforming (c).

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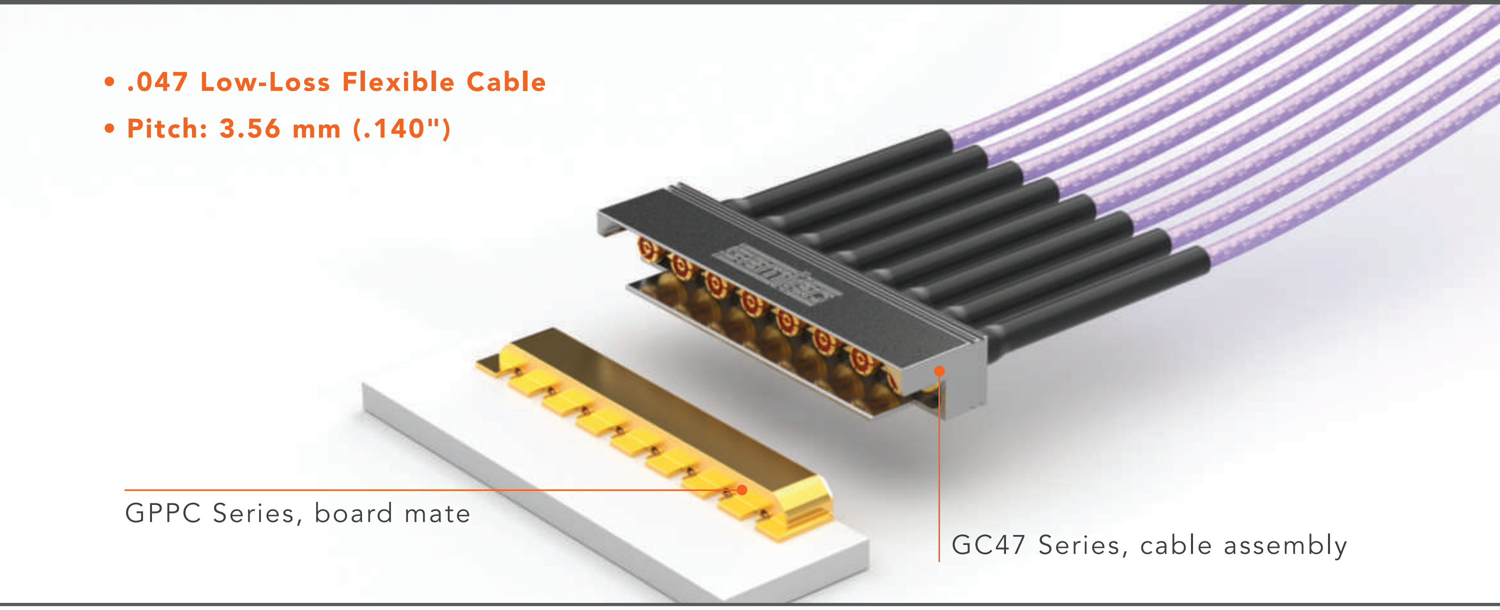

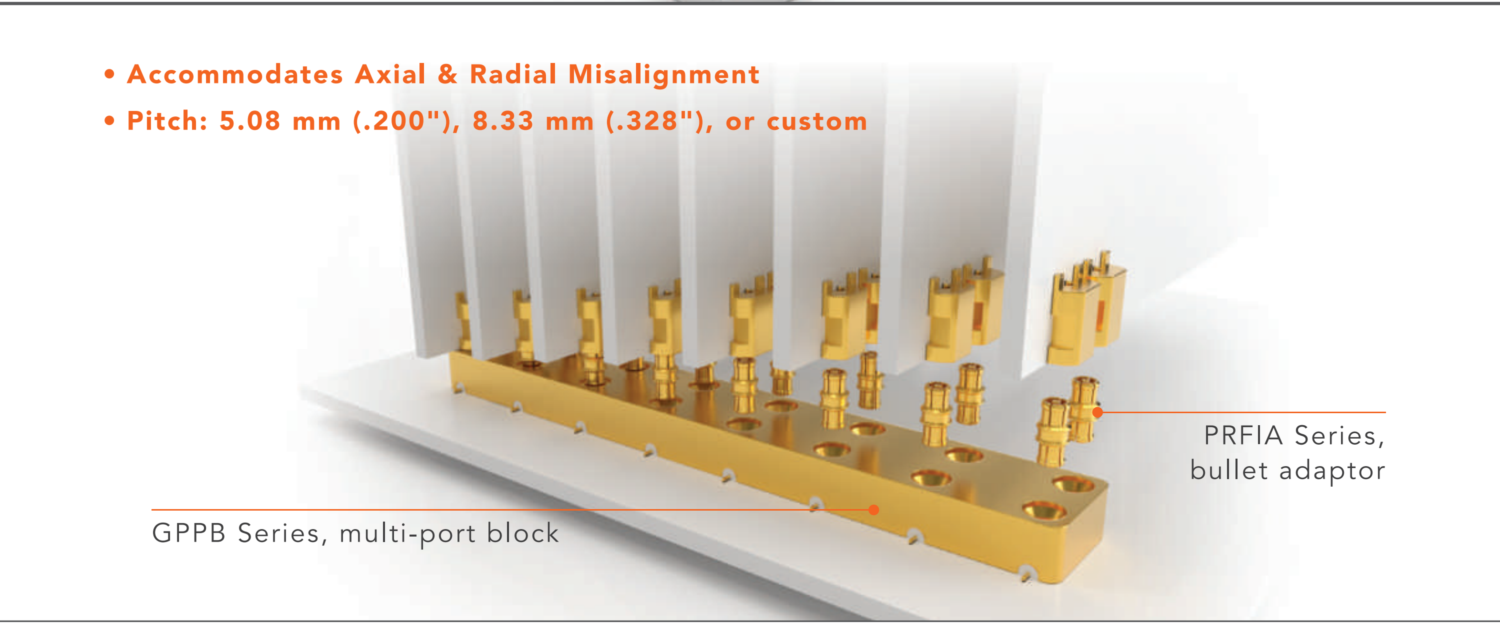

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For more information visit **samtec.com/PrecisionRF** analog hardware. Beam shape and direction are controlled by digitally adjusting the phase shifters along the RF paths. Analog beamforming is usually more cost-effective and less complex than digital beamforming; however, it can effectively support only a single beam, being restricted to the same signal for each antenna element. Multi-beam transmission is possible, but it is tedious and complex.[5] The antenna array is a full duplex (simultaneous transmission and reception), single aperture that uses frequency multiplexing with independently controlled transmit and receive channels for each radiating element.[1]

Although **digital beamforming** is like analog beamforming, it differs in that each antenna element has a dedicated RF-to-digital signal and path, rather than a single common RF chain (see ***Figure 2b***). Each individual path converts the RF signal to baseband (and vice versa) through RF mixers, ADCs and DACs. In this way, each path allows independent beam control, as phases and amplitudes can be controlled digitally through baseband processing. This increase in control allows multi-stream signal processing at the element level and enables the possibility to serve multiple users simultaneously through multiple physical beams.

One of the major challenges of the digital beamforming architecture is the distribution of local oscillator (LO) signals used for the mixers of each channel. The coherence of the LO affects the beam patterns and the system phase noise. In addition, digital beamforming structures consume high amounts of power due to demanding processor performance requirements.[5]

Hybrid Beamforming combines aspects of analog and digital beamforming. It uses digitally controlled RF chains that are further complemented by analog splitters and analog phase shifters (see ***Figure 2c***). Fewer RF chains are therefore needed, which decreases total power consumption. The number of antennas used in hybrid beamforming are significantly higher than the number of A/D converters, which results in a smaller number of supported data streams. That said, hybrid beamforming is a reasonably priced alternative to digital beamforming because it consumes less power while still allowing multi-stream transmission.[5]

Figure 2c is a block diagram of the receive side of an active hybrid ESA. It comprises an array of antenna elements partitioned into multiple analog beamforming sub-arrays, a digital beamformer on the sub-array outputs and a control path back to the analog phase shifters. This reduces the size of the digital beamformer by a factor equal to the average number of elements in each sub-array. It provides an efficient means of producing large, high gain adaptive antenna arrays at relatively low cost.[6]

Passive Beamforming

Liquid-crystal (LC)-based passive beamformers have been designed for Ku/Ka-Band UTs. This type of

array operates using the principle of phase delay in RF planar transmission lines on a LC substrate. By applying and controlling a DC voltage bias across the LC layer, one can adjust the alignment of the LC molecules in the substrate and change the associated dielectric constant to introduce phase delay to a signal on the transmission line.

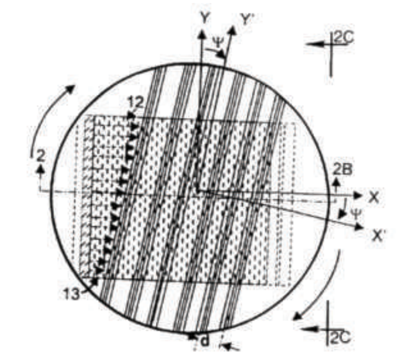
Without active electronic amplifiers, the passive beamforming array has significantly lower DC power consumption than an active array, and a more straightforward antenna architecture as well. However, the passive antenna panel size is usually larger due to intrinsic losses of the LC and other PCB materials. The LC molecules' time response (on the order of milliseconds) can result in slow array beam switching and cause temporary UT-satellite radio link interruption during handover in a LEO satellite system. The molecular response time also depends on operating temperature, so an additional heater may be required to maintain performance for operation in an extreme environment.

VICTS ANTENNA

A VICTS antenna is a type of passive flat panel aperture antenna consisting of multiple stacked disks that mechanically rotate around a single axis to achieve azimuth and elevation beam scanning.[7] The most basic VICTS antenna uses two disks, an upper disk and a lower disk. The upper disk has long parallel slits cut through it that enable electromagnetic waves to propagate. These slits are the radiating elements of the aperture and are known as continuous transverse stubs. The lower disk contains one, or more, line sources that produce electromagnetic waves. The space between the upper and the lower disk acts like a planar waveguide structure carrying the electromagnetic waves that feed the radiation.

Figure 3 demonstrates the upper plate being rotated relative to the lower plate by some angle, Ψ. As seen in the figure, the wavefront of the guided waves between the two disks becomes inclined to the transverse stubs. This inclination between disks creates a phase delay between the radiated waves in each of the stubs and steers the beam in elevation.[8] When both disks are rotated together, the antenna changes its scan angle in azimuth.

Disk rotation can be achieved in several ways including belt driven,



▲ Fig. 3 Top view of upper disk rotated relative to lower disk in a VICTS antenna.[8]

perimeter gear driven, direct gear driven or through magnetic induction.[8] More advanced VICTS antennas may have additional disks that serve to transmit or receive different polarizations other than the standard linear polarization of the basic VICTS architecture.[7]

One example uses a meanderline polarizer along with a grid line polarizer to change the polarization from linear to circular for transmit and from circular to linear for receive. A meanderline polarizer typically consists of at least one thin dielectric substrate layer on which conducting periodic meandering patterns are printed. The gridline polarizer is made using a similar structure and materials but consists of periodic parallel conducting traces. These two polarizers in the form of disks can be stacked on top of the VICTS apparatus with the meanderline polarizer above the gridline polarizer. The gridline polarizer pre-adjusts the angle of the linear polarization emitted from the VICTS antenna, ensuring an optimum axial ratio over frequency and scan, while the meanderline polarizer changes the polarization from linear to circular and vice versa. These two disks rotate as needed to achieve linear, right-hand or left-hand circular polarization while achieving an optimum axial ratio and impedance matching versus scan angle.[9]

Compared with the other flat panel antennas, VICTS antennas have a lower profile, a more simplistic design, higher radiation efficiency and fewer blind zones.[7,10] Although VICTS antennas are mechanically driven, they have fewer moving parts than other mechanically-driven antennas and thus have reliabilities comparable to ESAs. This is especially true for VICTS antennas that use magnetic induction for rotation.[8]

In addition, VICTS antennas have minimal blind zones in which element coupling is significantly reduced in some scan regions.[8] The blind zone in the VICTS antenna occurs when the beam is operating one to two degrees around the zenith, due to the wave propagating along the surface of the antenna instead of radiating outwards. Its large scanning range is an advantage over many 2D scanning phased arrays whose densely packed elements cause energy to be absorbed by adjacent elements when scanning at low scan angles.[11] Furthermore, VICTS antennas use less energy and emit less heat than ESAs because they have less electronic components.[8]

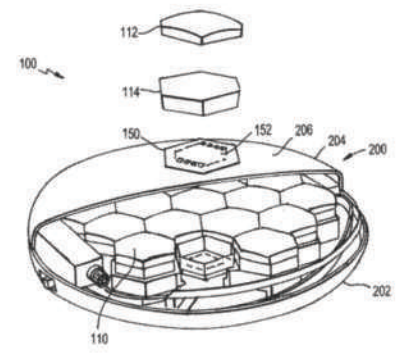
LENS ANTENNA

A lens antenna is a type of phased array comprising modular lens sets that integrate radiating elements or feeds with lenses made of low loss dielectric materials shaped with specific curvatures. The gradient index (GRIN) lens is preferred in most applications due to its flat surfaces, wide scanning range and short focal length.[12] Some applications use multi-layer composite dielectric lenses for ease of manufacturing with acceptable impedance matching and optical properties.

The optical properties of each lens set enhances directivity by focusing a plane wave to a small radiating element or feed at the RF front-end.[13] This effectively downsizes the array number, reduce the overall cost of electronic components and DC power consumption. Most lens designs also enable optical off-axis focusing, which provides additional beam scanning flexibility for array operation. The overall antenna system, however, still uses an active analog or digital beamforming architecture for RF signal conditioning.

Depending on its architecture, a lens antenna can operate with two levels of beam scanning (coarse and fine beam pointing) to jointly steer the beam. Coarse beam pointing is executed by the lens set and front-end circuitry to create a directive broad beam that is steered by shifting the location of a feed element in relation to the focal point of the lens. This shift is either performed by electromechanical actuators or by electronically enabling or disabling feed elements within a small front-end feed array. Fine beam pointing is then done by combining corresponding feed elements in each lens of the array with phase shifts or time delays in the analog or digital beamforming networks.

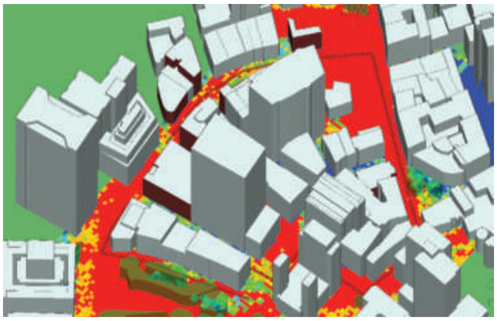
The lens antenna architecture supports multi-beam operation in a single aperture. Multiple beams can be created by locating multiple feeds at different focal points of a lens. Each feed is connected to an individual RF circuit and associated network for independent beamforming. A large element spacing due to the physical size of each lens can create unwanted grating lobes. These grating lobes can be

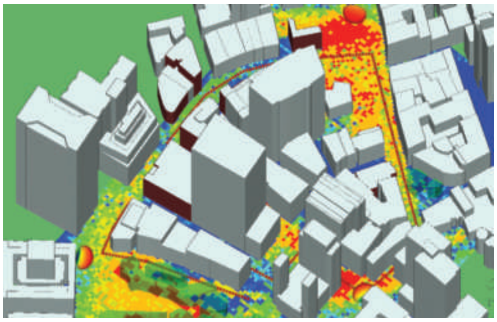


▲ Fig. 4 Cutaway view of a lens antenna.[12]

TABLE 1
FLAT PANEL ANTENNA TECHNOLOGIES FOR BROADBAND LEO CONSTELLATIONS (ASSUMES GIVEN EIRP AND G/T)

	Active Analog	Active Digital	Active Hybrid	Passive Analog	VICTS[15,16]	Lens[17]
Size	Medium	Medium	Medium	Large	Small	Medium
Weight	Light	Light	Light	Medium	Heavy	Medium
Power Consumption	High	High	Medium	Low	Low	Low
Cost	Medium	High	High	High	Medium	Medium
Manufacturer	Ball	SatixFy	SpaceX	Alcan Systems	ThinKom	Isotropic Systems

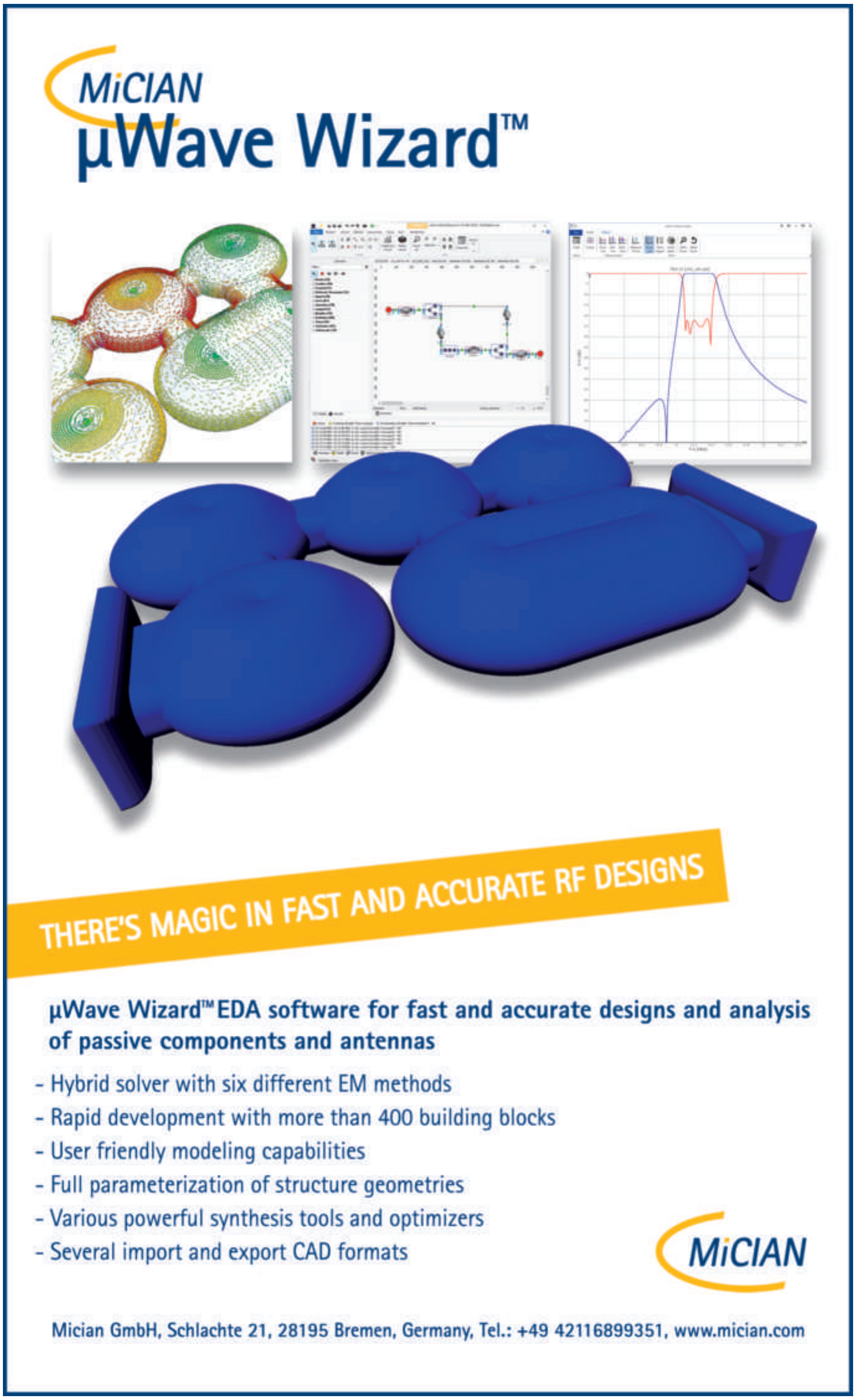




Beamforming with massive MIMO (top) shows significant improvement to throughput over links between single antennas (bottom) minimized by steering element patterns or by offsetting the phase center of each lens to break up the array periodicity.[12]

Figure 4 shows one concept of a lens antenna. Each lens set includes the lens (112), the lens spacer (114) and the feed set (150) with its respective feed element(s) (152).[12] With this setup, each lens set is enabled as needed for multiple beams, high bandwidth and low power.[14]

The unique characteristics of the lens antenna provides advantages over a conventional phased array.[16-17] With lens-assisted aperture directivity, it uses significantly less elements, reducing the active circuitry per beam for less power consumption and heat generation. In addition, some lens designs provide optical properties that enable elevation scanning with better directivity roll-off compared to the typical flat panel ESA.



TECHNOLOGY COMPARISON AND CONCLUSIONS

In ***Table 1***, ESA, VICTS and lens antenna technologies are compared in terms of SWaP-C for LEO broadband communications constellations. Design challenges are identified for each.

A flat panel antenna's ability to track and perform satellite-to-satellite handovers makes it a critical element of a broadband satellite system. Current Ku-/Ka-Band UT flat panel antennas are described and compared. The ESA's multiple arrays of individual radiating antenna elements enables it to steer main and null beams toward specific locations with differences in strength and beamwidth depending on the number of radiating elements.

Three ESA beamforming techniques are analog, digital and hybrid. Analog beamforming is the simplest to implement, using one signal to steer the beam by shifting its phase for each antenna element. Due to its single RF chain, however, it can usually only steer one beam. Digital beamforming uses a dedicated signal for each antenna element, enabling independent control of multiple beams through baseband processing at the expense of prime power and cost. Similarly, hybrid beamforming accomplishes beam steering with a reduced number of RF chains combined with analog phase shifters. The combination of digital and analog beamforming techniques is limited to a smaller number of data streams but is less expensive than digital beamforming.

The VICTS antenna employs a simple structure of rotating mechanical disks allowing minimal blind zones while still radiating high energy.

The lens antenna's modular lens allows for a lightweight terminal with different options in terms of gain, scanning range and relative transmit and receive performance.

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K-Band Highly Linear Power Amplifier with Superior Temperature Stability in 90 nm Trap-Rich SOI-CMOS

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A K-Band stacked-field-effect transistor (FET) power amplifier (PA) with high linearity and superior temperature stability is implemented in 90 nm trap-rich high-resistance SOI-CMOS technology. The PA adopts a two-stacked-FET architecture and low loss coplanar waveguide (CPW) matching networks to improve the RF output power and power-added efficiency (PAE). The PA with an area of 0.63 mm² demonstrates a peak power gain of 14.6 dB at 23.5 GHz, a saturated output power of 14.2 dBm with a 3 dB bandwidth of 6 GHz and a peak PAE of 23.5 percent. The measured output third intercept point (OIP3) of 28.4 dBm represents a high linearity feature for 5G communication applications. The RF characteristics at different temperatures from -40°C to 125°C demonstrate superior temperature stability for automotive radar applications.

K-Band MMICs for 24 GHz automotive radar and 5G communication applications have drawn widespread attention in recent years. Typical K-Band MMICs were typically realized in expensive SiGe BiCMOS and GaAs pHEMT technologies.[1-3] Thanks to continuously improved cut-off frequencies of highly scaled CMOS transistors, advanced MMICs based on CMOS technologies can now meet the cost and integration requirements for these high frequency electronic systems.[4-7] K-Band PAs fabricated in bulk silicon CMOS technologies, however, encounter severe performance degradation in high temperature environments, such as near car engines.[5]

K-Band PA linearity for 5G applications is an important property that is hard to achieve in bulk CMOS, however.[6] SOI-CMOS technologies utilized in the production of ICs for high temperature applications and can provide higher cut-off frequencies, better linearity and lower loss passive components than bulk CMOS. Consequently, SOI-CMOS technology has become a cost-effective choice for high performance K-Band applications.

In this article, a K-Band stacked-FET PA with high linearity and superior temperature stability is implemented in 90 nm trap-rich high-resistance SOI-CMOS technology. The cut-off frequency of the SOI nMOSFET is higher than 90 GHz. A common source architecture is used in the drive stage and a two-stacked-FET architecture is chosen for the output stage. Small and large-signal measurements verify linearity, and temperature stability is measured from -40°C to 125°C.

PA DESIGN

Stacked-FET Architecture

The PA in this work is designed for high linearity and high temperature stability based on a trap-rich SOI-CMOS process. ***Figure 1*** shows the full schematic of the single-ended two-stage architecture, including a drive stage and an output stage. Each MOSFET operates Class A.

Generally, the output power of


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a PA fabricated in highly scaled Si CMOS technology is limited mainly by its low breakdown voltage; however, the stacked-FET configuration distributes the swing voltage equally in each MOSFET. Theoretically, a k-stacked-FET architecture can tolerate k times the breakdown voltage, improving output power and reliability. The most important aspect of the design is the load impedance seen at the drain for each MOSFET. Consequently, a small capacitor is connected to the gate of the common-gate MOSFET M3 in parallel to tune the load impedance seen at the drain of M2 and control the drain-source swing voltage of M2 and M3.

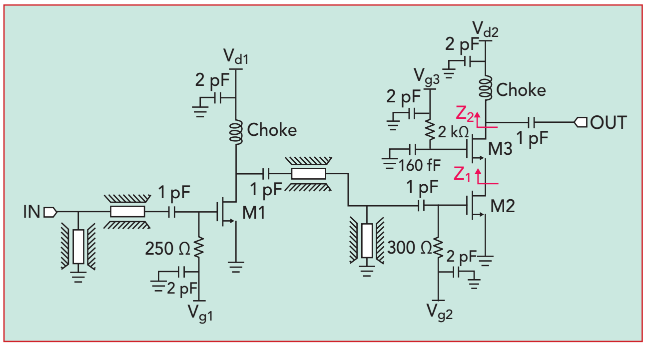

Fig. 1 Single-ended, two-stage PA architecture.

Design of CPW Lines and Inductors

The inductors and CPW line structures usually encounter high substrate-induced losses due to the relatively high substrate conductivity in the bulk CMOS process. In this work, a trap-rich high-resistance substrate provides low dielectric losses and low cross talk in the PA blocks. The input and inter-stage matching network are designed using CPW lines. High-quality factor multi-turn RF-choke inductors are made with two layers of thick copper interconnects. They may also be realized using CPW, however, a long CPW line leads to a larger chip area.

In a sub-100 nm CMOS process, the requirements for RFIC design are stringent. Small floating metallization called dummy fill is used to adjust the metal density and suppress the thickness variation of interconnects; however, dummy fill can influence the electrical performance of transmission lines and inductors used in microwave and mmWave circuits.[8] Consequently, the use of dummy fills should be considered carefully. As shown in ***Figure 2***, dummy fills under CPW lines are removed to minimize the impact to microwave passive components.

Output Stage MOSFET Sizes and PA Stability

The load-line method is used and the optimum load impedance (R_{opt}) is calculated for high output power. Tradeoffs are considered carefully in this design to determine output power, R_{opt} and output stage MOSFET size. Generally, a larger MOSFET can provide higher output power and smaller R_{opt}; however, a large size MOSFET is usually designed with gate fingers in parallel, which can form an extremely small input impedance and make it difficult to design a wideband input matching network. In the design of this PA, the size of the output stage MOSFET is 3.125 μm × 32 fingers to minimize the effect of gate series resistance. According to the simulation results, the largest drain-source voltage for M2 and M3 is around 2.4 V. Maximum drain current is almost 80 mA, and the knee voltage for M2 and M3 is about 0.3 V. For a single MOSFET,

$$R_{opt} = \frac{2.4 - 0.3}{0.08} = 26.25\ \Omega \quad (1)$$

$$P_{out} = \frac{1}{8} \times (2.4 - 0.3) \times 80 = 21\ \text{mW} \approx 13.2\ \text{dBm} \quad (2)$$

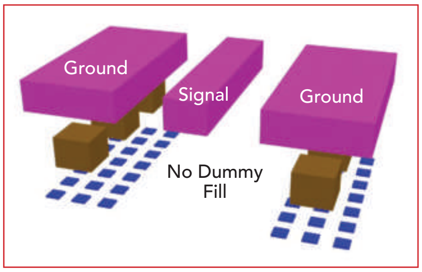

Fig. 2 CPW line without dummy fill under the signal line.

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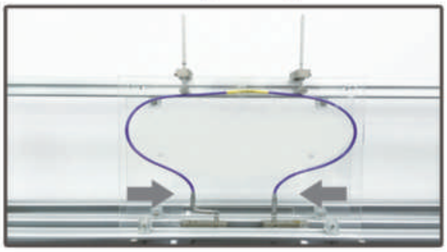

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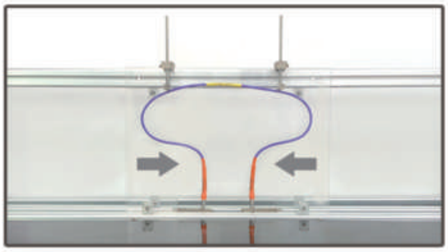

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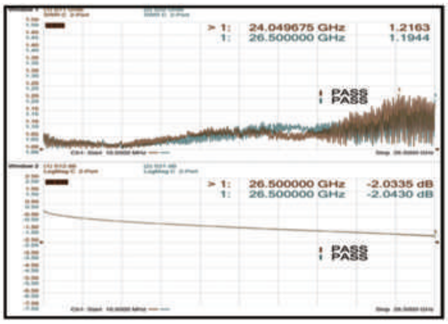

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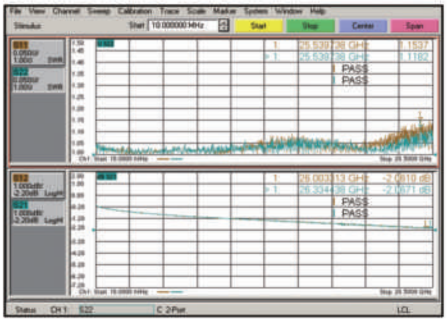

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P_{out} is the output power estimated empirically. For a two-stacked-FET architecture, an additional 3 dB power gain can double the output power to 16.2 dBm, which is a suitable value for point-to-point wireless communication permitted by the Federal Communications Commission (FCC). The band from 22 to 29 GHz has also been opened by the FCC for short range radar applications. Large bandwidth versus high output power is needed in this application.

The load impedance (Z_2) seen at the drain of M3 is tuned to $2R_{opt}$, which is 52.5 Ω and close to the standard 50 Ω load impedance. Consequently, an output matching network is not required and the circuit area is reduced. The impedance (Z_1) seen at the drain of M2 is tuned to R_{opt}, which is 26.25 Ω. The simulated real and imaginary parts of Z_1 (see ***Figure 3***) show the impedance optimized to approximately 26 Ω from 20 to 30 GHz with a 160 fF capacitor connected to the gate of M3.

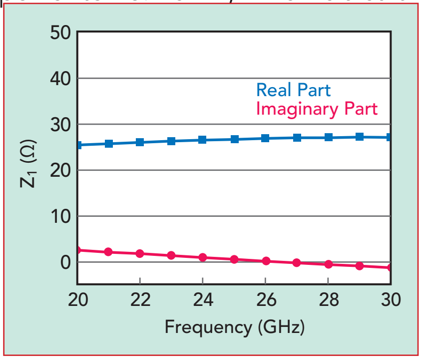

Fig. 3 Simulated Z_1 vs. frequency.

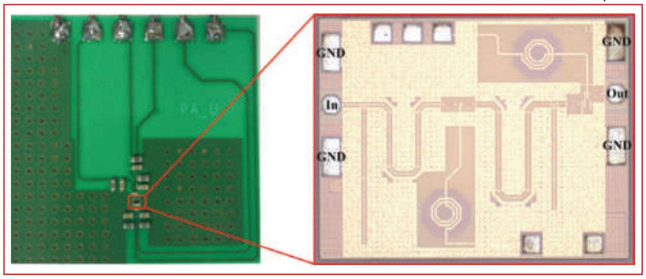

Fig. 4 MMIC PA and characterization board.

Small resistors connected to the gates of M1 and M2 are used to supply bias voltages and enhance circuit stability. A 2 pF MIM decoupling capacitor is connected to each biasing pad in parallel to minimize the influence of bonding wires, which also aids stability. The Rollett stability factor, K, of the PA is simulated and is greater than 1 for all frequencies between DC and 30 GHz. Transient simulation confirms that each output stage MOSFET has the same swing voltage at high output power, especially at high drive level.

MEASURED RESULTS

Figure 4 shows the printed circuit board (PCB) for chip measurements and a microphotograph of the PA. The area of the entire chip is 0.9 × 0.7 mm including pads. The PCB provides DC bias for the PA with 1 and 10 µF capacitors added in parallel. Vdd of the drive stage is 1.2 V and Vdd of the output stage is 2.4 V. Infinity ground-signal-ground microprobes are used for on-chip measurement. No signs of oscillation at any drive level or wire bond inductance are observed.

Small-signal measurements are conducted using a Keysight E5247 network analyzer (see ***Figure 5a***).

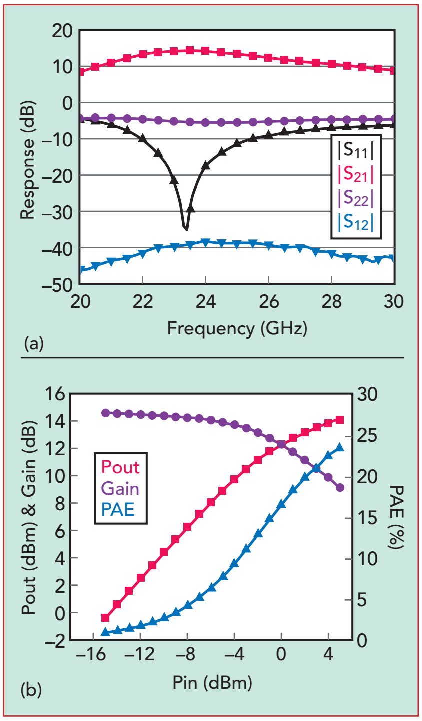

Fig. 5 PA small- (a) and large-signal (b) performance.

The input port of the circuit is designed to match with 50 Ω at 24 GHz. The 3 dB bandwidth is about 6 GHz from 21.1 to 27.1 GHz, while 14.6 dB peak gain is achieved at 23.5 GHz. S_{11} is lower than -10 dB from 22 to 25.4 GHz with S_{22} around -5 dB without an output matching network. S_{12} of the PA across the 20 to 30 GHz band is lower than -38 dB, which indicates a high level of reverse isolation.

Large-signal measurements (see ***Figure 5b***) show output power, power gain and PAE. The PA can produce 14.2 dBm of saturated output power with 10.5 dBm OP_{1dB} at 23.5 GHz. The measured maximum output power is slightly lower than simulated due to parasitic effects. The maximum PAE is 23.5 percent.

Two-tone measurements verify the linearity. The two tones are applied at 23.5 GHz and 23.52 GHz using analog signal generators. The signals are combined through a magic tee and the outputs are captured by a signal analyzer. ***Figure 6*** shows the linearity of the PA and measured OIP3 of 28.4 dBm. This is 14.4 dB higher than reported by Komijani et al.,[6] for a PA in bulk CMOS. This demonstrates that PAs with high linearity can be achieved using trap-rich SOI-CMOS technology.

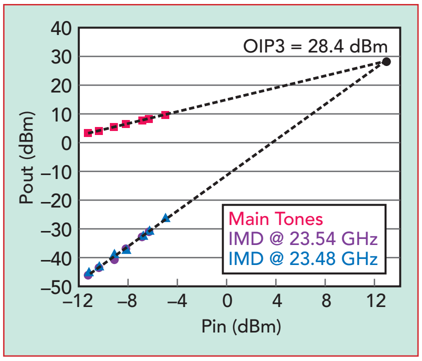

Fig. 6 PA two-tone measurements and calculated OIP3.

A high and low temperature semiautomatic probe station is used to measure RF performance at different temperatures (see ***Figure 7***). Output power, gain and maximum PAE for the PA at -40°C are 15.4 dBm, 16.7 dB and 30.2 percent, respectively. A slightly degeneration in RF performance is observed at 125°C, but the chip can still provide a peak gain of 11.5 dB, an output power of 12.6 dBm and a peak PAE of 18.3 percent.

PA gain for devices fabricated in bulk CMOS reported by Dawn et al.[5] shows 7.7 dB degeneration at 80°C compared with room temperature. This PA designed in trap-rich SOI-CMOS technology demonstrates superior temperature performance without any temperature compensating circuits. It is an important consideration for automotive electronics applications where cooling is inappropriate or not possible.

CONCLUSION

A K-Band stacked-FET PA in 90 nm trap-rich high-resistance SOI-CMOS technology with high linearity and superior temperature stability uses a two-stacked-FET architecture and low loss coplanar waveguide matching networks to


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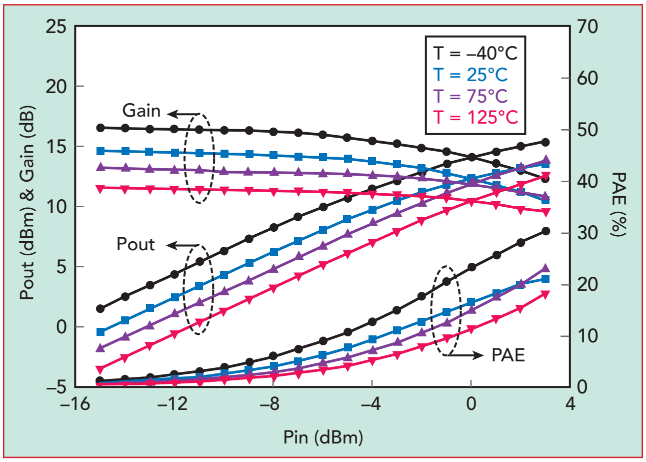

Fig. 7 Measured output power, gain and PAE over temperature.

improve the RF output power and PAE. Dummy fills in the lower layer are removed to minimize the influence on CPW lines and multi-turn inductors. Sizes of stacked MOSFETs are optimized to omit the output matching network and reduce chip area. ■

ACKNOWLEDGMENT

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Improving Linearity of a Doherty Power Amplifier with a Dual-Bias Structure

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A novel dual-bias circuit structure increases a power amplifier's video bandwidth while reducing the memory effect, thereby improving its linearity. A Doherty power amplifier (DPA) operating in the 5G communication band (3.4 to 3.6 GHz) and incorporating this circuit achieves a saturated output power of 43 to 44 dBm with a saturated drain efficiency greater than 70 percent. Drain efficiency is 51 to 55 percent at 6 dB power back-off and greater than 43 percent at 8 dB back-off. As output power reaches 42.7 dBm, the adjacent channel leakage ratio (ACLR) is less than -46 dBc combined with digital predistortion (DPD).

For increasing the data transmission rate and the capacity of wireless communication systems, modulation signals with high peak-to-average power ratios (PAPR) are widely applied, and DPAs have become the mainstream for base station power amplifiers.[1-4] Correspondingly, video bandwidth (VBW) and memory effect are two important factors in Doherty RF power amplifier performance.[5]

VBW plays a significant role in the operating bandwidth of the PA and affects the degree of DPD correction.[6] If the instantaneous signal bandwidth is very close to the VBW, PA linearity is seriously deteriorated and is difficult to correct with DPD.[7,8] It can also cause large voltage and current offsets in the active device, resulting in high internal temperatures and component damage.

Several methods to decrease the memory effect and enlarge VBW have been proposed.[9,10] Ladhani et al.[9] obtained wider VBW by directly connecting series resonant circuits to the gate and drain electrodes of a transistor die in a package. This method is based on the design of the transistor current plane and is not suitable for practical circuit design. In addition, an LC resonant bias network has been proposed to diminish baseband impedance for reducing the electrical memory effect;[10] however, the harmful effect of this method is that the fundamental impedance decreases while reducing the baseband impedance. The smaller fundamental impedance causes RF power to leak into the bias circuit. Furthermore, lumped-parameter components with large parasitic elements are difficult to use in RF circuits.

This article describes a high efficiency and high linearity 3.4 to 3.6 GHz DPA with a novel dual-bias network structure to broaden the VBW and minimize memory effects in a wideband DPA when transmitting a 20 MHz A-LTE modulation signal. With the addition of linearization technology, this DPA exhibits good linearity and high efficiency.[11-16]

KEY TECHNOLOGIES

Memory Effect

In a field-effect transistor amplifier, the majority of undesirable memory effects are attributed to the baseband impedance, and the baseband impedance is mainly determined by the impedance of the bias network in the low frequency band.[17,18] When employing DPD in an RF PA it is particularly important to reduce the memory effect. The baseband impedance, Z, should be short-circuited at low frequencies (see ***Figure 1***); but unfortunately, it is not. The presence of baseband impedance causes the voltage at the drain of the power transistor to change with input signal level. To reduce memory effect, the baseband impedance of the drain bias must be minimized.

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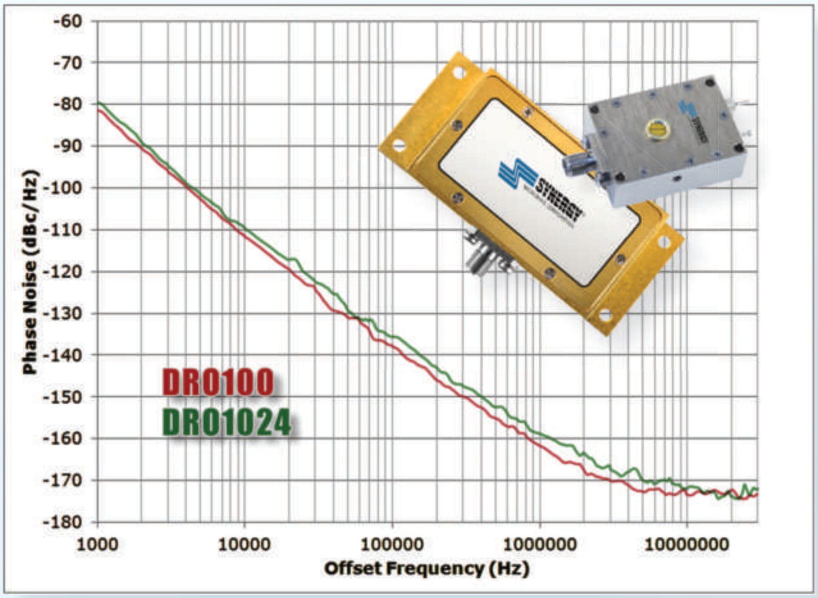

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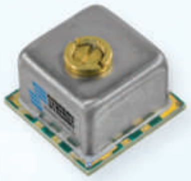

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SDRO900-8	9.000	1 - 10	+8.0 @ 25 mA	-112
SDRO1000-8	10.000	1 - 15	+8.0 @ 25 mA	-107
SDRO1024-8	10.240	1 - 15	+8.0 @ 25 mA	-105
SDRO1118-7	11.180	1 - 12	+5.5 - +7.5 @ 25 mA	-104
SDRO1121-7	11.217	1 - 12	+5.5 - +7.5 @ 25 mA	-106
SDRO1130-7	11.303	1 - 12	+5.5 - +7.5 @ 25 mA	-106
SDRO1134-7	11.340	1 - 12	+5.5 - +7.5 @ 25 mA	-107
SDRO1250-8	12.500	1 - 15	+8.0 @ 25 mA	-104
SDRO1300-8	13.000	1 - 12	+8.0 @ 25 mA	-104
SDRO1400-8	14.000	1 - 12	+8.0 @ 25 mA	-102
SDRO1500-8	15.000	1 - 12	+8.0 @ 25 mA	-100
Connectorized Models				
DRO80	8.000	1 - 15	+7.0 - +10 @ 70 mA	-114
DRO8R95	8.950	1 - 10	+7.0 - +10 @ 38 mA	-109
DRO100	10.000	1 - 15	+7.0 - +10 @ 70 mA	-111
DRO1024	10.240	1 - 15	+7.0 - +10 @ 70 mA	-109
DRO1024H	10.240	1 - 15	+7.0 - +10 @ 70 mA	-115
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VBW

In modern communication systems, wide bandwidth and multi-carrier modulation have been used for high speed data transmission. Nevertheless, the modulation signal bandwidth is limited by RFPA VBW. VBW depends mainly on the equivalent LC resonance of bias networks and transistor internal matching. ***Figure 2*** is the equivalent circuit model of a transistor and a typical bias circuit. The equivalent resonant frequency can be expressed as:

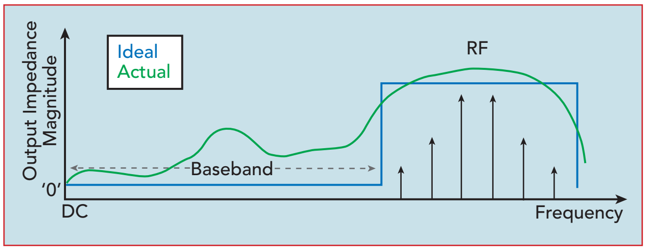


Fig. 1 Ideal vs. actual RF impedance.

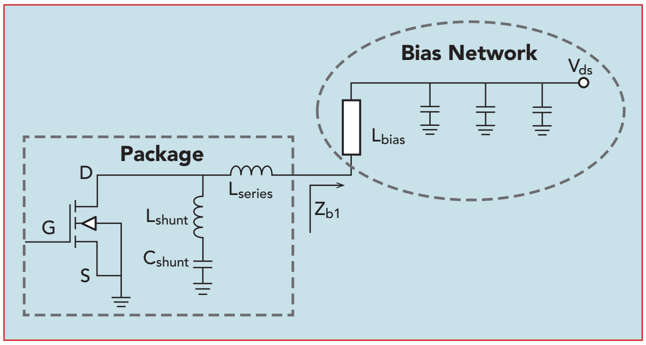


Fig. 2 Typical transistor bias circuit.

$$f = 1/(2\pi \mathrm{sqrt}(L_m C_{shunt} t)) \tag{1}$$

Where, L_m is the typical bias circuit equivalent inductance and $L_m = L_{shunt} + L_{series} + L_{bias}$. C_{shunt} represents the shunted equivalent transistor package capacitance.

In general, L_{bias} is higher than L_{shunt} and L_{series} by more than two orders of magnitude. So, $L_m \approx L_{bias}$. Therefore, widening of the VBW can be achieved by reducing the equivalent inductance of the bias circuit.

Dual-Bias Network

Optimizing the memory effect requires reducing the baseband impedance, and increasing the VBW requires increasing the equivalent LC resonant frequency. A novel dual-bias network that does this is shown in ***Figure 3***. Compared with a typical bias circuit, the dual-bias network is simply two bias circuits in parallel. From the principle of parallel circuits:

$$Z_{b1} = 2Z_{b2} \tag{2}$$

Where Z_{b1} and Z_{b2} are the drain bias impedances in Figures 2 and 3, respectively. Because the drain node impedance of the dual-bias network is half that of the typical bias circuit, baseband impedance is reduced

and the memory effect improved.

L_{bias} and L_{bias}' in Figure 3 are λ/4 microstrip lines with equivalent parallel inductance of 1/2 L_{bias}. The equivalent resonant frequency is:

$$f = 1/\left(2\pi \mathrm{sqrt}\left(L_n C_{shunt} t\right)\right) \qquad (3)$$

where, L_n is the dual-bias circuit equivalent inductance and $L_n = L_{shunt} + L_{series} + ½ L_{bias}$.

The Cree CGH40010F transistor is used as an example. At a center frequency of 3.5 GHz, the transistor equivalent model is analyzed and the λ/4 microstrip lines equivalent inductance is calculated. L_{shunt} and L_{series} are lower than L_{bias} by an order of magnitude; therefore, L_n can be expressed as:

$$L_n = L_{shunt} + L_{series} + \frac{1}{2} L_{bias} \sim \frac{1}{2} L_{bias} \qquad (4)$$

Advanced Design System (ADS) is used to simulate the two bias circuits. The results plotted in ***Figure 4***, show the resonant frequency of the dual-bias network to be about 1 GHz, more than twice the resonant frequency of a typical single bias network, which increases the VBW while reducing the baseband impedance.

IMPLEMENTATION AND MEASUREMENT RESULTS

The dual-bias network is verified with a DPA designed for 5G mobile communications in the frequency band of 3.4 to 3.6 GHz. ***Figure 5*** is a photograph of the dual-bias DPA. It is fabricated on a 30 mil thick Rogers RO4350B substrate with a 3.48 dielectric constant. Cree CGH40010F GaN HEMTs are used for both the carrier and peaking amplifiers. The carrier amplifier is set to Class AB with a gate bias of -2.75 V. The peaking amplifier operates in Class C with gate bias of -6 V. Referring to the transistor datasheet, the drain operating voltages of both amplifiers are set to 28 V.

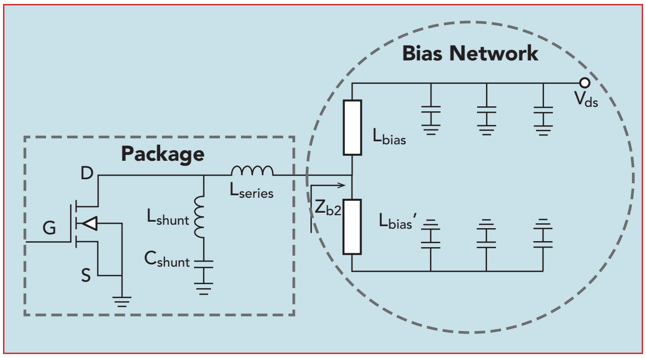
The curves of the gain and efficiency of the DPA as a function of output power are shown in ***Figure 6***. Saturated output power can reach more than 43 dBm. Compared with the simulated efficiency, at low output power, the measured efficiency is higher and at higher output power, the measured efficiency is about three percentage points lower. The drain efficiency at saturation is above 70 percent. When the output power is backed off 6 dB, it is in the range of 51 to 55 percent. The efficiency is higher than 43 percent when the output power is backed off by 8 dB. Measured gain is slightly lower than simulated. When approaching saturated output power, gain appears to compress, but the average measured gain is greater than 10 dB.

At the 3.5 GHz center frequency a 20 MHz LTE modulation signal with a peak-to-average power ratio of 7.1 dB is used to drive the DPA. The measured ACLR is shown in ***Figure 7***. Upper and lower sidebands are -32.1 and -31.9 dBc, respectively, with an output power of 42.7 dBm. After the addition of DPD they are -46.6 and -47.5 dBc, respectively.

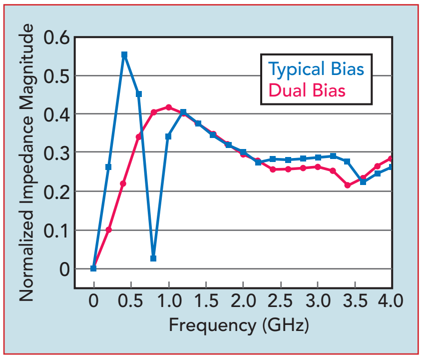
Table 1 provides a performance comparison with other published DPAs, showing improved drain efficiency and ACLR.

CONCLUSION

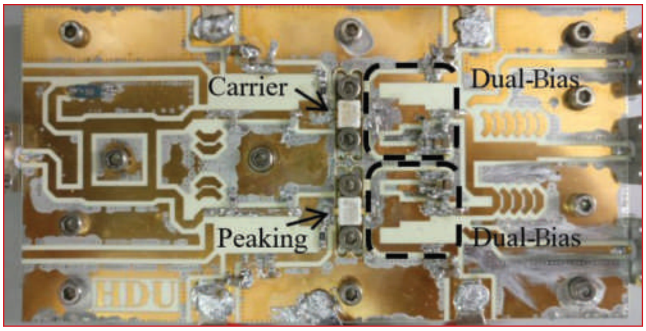
A new type of dual-bias network structure widens RFPA VBW and reduces the memory effect. To verify this, a DPA operating from 3.4 to 3.6 GHz is designed and fabricated. The ACLR measured with DPD is lower than -46 dBc when using a 20 MHz LTE modulation signal with a PAPR of 7.1 dB. This shows that the dual-bias struc-



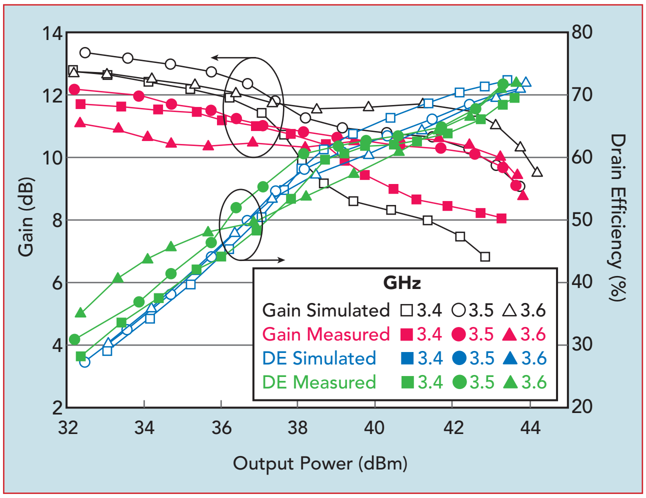
▲ Fig. 3 The dual bias circuit increases the equivalent LC resonant frequency.



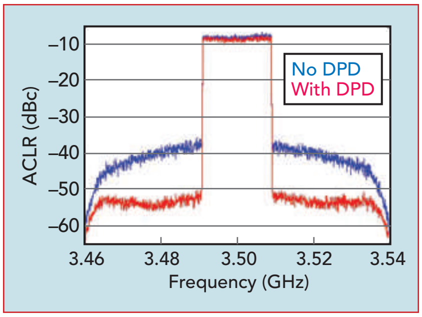
▲ Fig. 4 Simulated impedance vs. frequency of the typical and dual bias circuits.



▲ Fig. 5 Fabricated GaN DPA.



▲ Fig. 6 Measured and simulated gain and drain efficiency vs. output power, 3.4 to 3.6 GHz.



▲ Fig. 7 Measured ACLR at 3.5 GHz.

ture not only widens the VBW and reduces the memory effect, but is also easily implemented. ■

ACKNOWLEDGMENTS

This work is supported by National Natural Science Foundation of China (No. 61871169).

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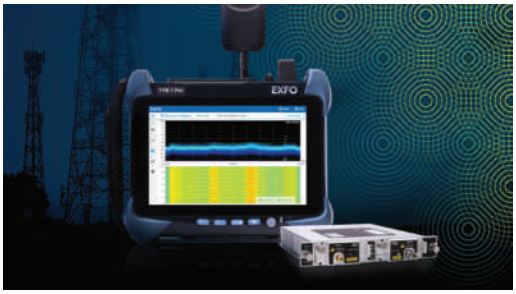
TABLE 1

PERFORMANCE OF PUBLISHED DPAS

Ref.	Frequency (GHz)	Gain (dB)	P_{out} (dBm)	Drain Efficiency (%)	ACLR (dBc)	PAPR (dB)	Modulation Signal Bandwidth (MHz)	Modulation Signal
11	3–3.6	10	43–44	55–66	N/A	N/A	N/A	CW
12	2.6	7–10	51.7	60.4	-35.5	8.3	5	WiMAX
13	2.14	16.6	36.9	57.0	-25	6.5	10	LTE
14	2.2–2.3	11.6–13.6	45	62.9–71	-30	N/A	N/A	N/A
15	2.9	10–15	43.8	64.9	-21	N/A	5	WCDMA
10	0.7–0.86	10–14	49.3	42	-30	7.2	100	LTE
16	3.4–3.6	7–9.5	49.5	60	-29	8.5	100	LTE
This Work	3.4–3.6	8.5–12.2	43.8	> 70	-32	7.1	20	LTE



Demystifying 5G NR Measurements with a Spectrum Analyzer

EXFO
Québec, Canada

5G is pushing the boundaries of wireless communications, enabling use cases that rely on Gbps data rates, exceptionally low latency and ultra-high reliability. These stringent requirements need increased mobile network densification, with the installation and activation of many new cell sites and small cells. To deliver quality of service and ensure network performance, mobile network operators must deploy and validate these 5G sites accurately and efficiently. As they move to 5G, operators still need to support, maintain and test existing wireless technologies, i.e., 3G, LTE, as well as 5G-NR. This is already the reality for many operators, reflected in a recent EXFO survey where over 40 percent of respondents replied that wireless bands deployed in their regions included a mix of sub-2.4 GHz, sub-6 GHz and mmWave frequencies.

5G FIELD TESTING CHALLENGES

5G is presenting new challenges for mobile network operators, contractors and field service technicians to validate networks. The separation between fiber and RF environments is becoming blurry; it's less clear where one ends and the other starts. Given this evolving environment, these are the main challenges for 5G field testing:

- A new air interface is now deployed, with advanced technologies like mMIMO and beamforming making the RF environment more complex to navigate
- There are tighter constraints on network synchronization and any timing issues will impact RF performance: user equipment (UE) transmitting at the same time as the radio in time-division duplex (TDD) systems, cell sites interfering with each other, handover issues and slow to no throughput
- Analyzing spectrum can be difficult because of the wider bandwidths and more interference falling inside the channel, making troubleshooting a longer process. Intermittent signals such as TDD add complexity to the spectrum analysis
- To deploy 5G faster, the first non-standalone (NSA) 5G installations used 4G uplinks. Since 4G was powering these NSA networks, issues on the 4G network can degrade the 5G experience.

These operational challenges mandate new, innovative test processes. To get the most from their investments, operators need field-focused RF testing solutions that both scale and adapt as their networks change. To address this market requirement, EXFO

developed an innovative, modular RF testing solution that adapts as the networks evolve.

EXFO's 5GPro Spectrum Analyzer is the industry's first field-tech optimized, scalable RF spectrum analyzer that delivers accurate RF over-the-air (OTA) measurements. It's the only modular RF testing solution analyzing LTE and 5G NR environments, with the ability to analyze sub-6 GHz (FR1) and mmWave (FR2) bands using a compact, field-upgradable instrument. Designed for simplicity of use, the 5GPro Spectrum Analyzer enables field techs and contractors to easily identify and resolve issues and close out jobs faster.

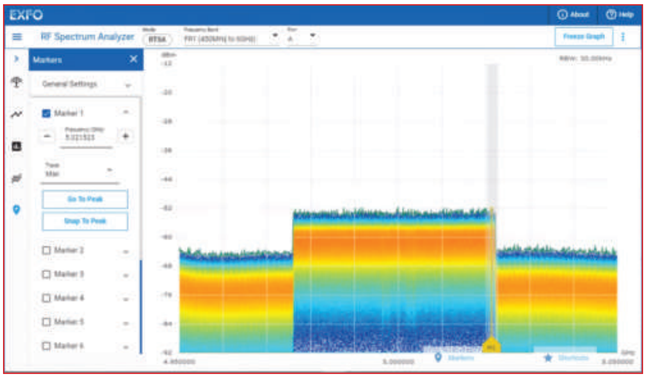


Fig. 1 The RTSA capability enables interfering signals to be easily identified.

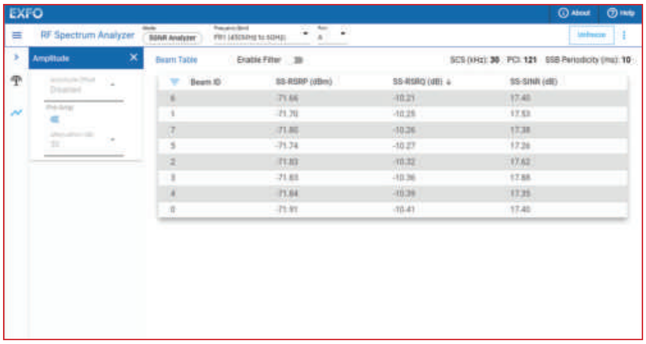


Fig. 2 The 5G NR signal analyzer supports mMIMO and beamforming characterization.

The 5GPro supports several complex test scenarios:

Catching Transient Interferers — Real-time spectrum analysis (RTSA) can show signals that are masked inside larger channel bandwidths. RTSA uses various color densities reflecting the intensity of the signal, enabling the interferer signal to be detected quickly (see ***Figure 1***). The 5GPro Spectrum Analyzer is an RTSA with 100 MHz of analysis bandwidth that provides continuous acquisition of RF signals. Quick characterization of wireless signals and detection of intermittent interference is possible using the RTSA's persistence and spectrogram view.

The 5GPro Spectrum Analyzer also brings innovation and intelligence to RF testing with a smart user interface, featuring built-in expertise and patent-pending features like intelligent peak detection and "snap to peak." With snap to peak, field techs can use the touch screen to identify interferers with a moveable window, enabling the user to easily search for the highest amplitude interferer and attach a marker.

5G NR Signal Analyzer — The 5G NR signal analyzer capabilities of the 5GPro enable analyzing complex technologies like mMIMO and beamforming. A quick check of power parameters of the synchronization signal block validates whether all beams are being transmitted. As an example, ***Figure 2*** shows a signal in the CBRS band around 3.5 GHz. If the cell site is operating correctly, the signal analyzer should receive eight beams (0 to 7), with RSRP, RSRQ and SINR for each beam.

The 5GPro Spectrum Analyzer supports the demodulation of 5G NR signals and can validate OTA performance of cell sites to ensure smooth communication with UE. This application will analyze up to 64 beams and display the 12 strongest, showing the corresponding power measurements and beamforming metrics.

As LTE is not going away soon, the 5GPro Spectrum Analyzer also demodulates LTE signals and provides key metrics, including sector and group ID, physical cell ID (PCI), duplexing mode (frequency or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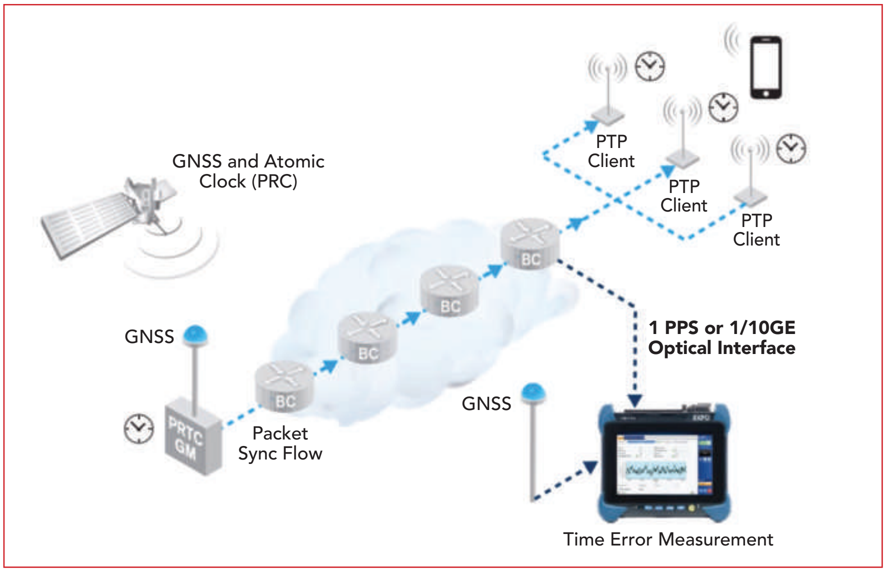

Fig. 3 A time error measurement used to validate timing accuracy at various points in the network.

time), RSRP (dBm), RSRQ (dB) and RSSI (dBm).

Spectrum Analysis using Gated Sweep — TDD is a transmission protocol where the uplink and downlink signals are transmitted on the same frequency using synchronized timed intervals. Spectrum and interference analysis for TDD require the use of a measurement technique called gated sweep, which visualizes the uplink or downlink spectrum by only displaying data within a specified range of timeslots. The 5GPro Spectrum Analyzer can display TDD uplink or downlink signals with a simplified gated sweep, saving time when analyzing the spectrum or interference.

Validate Timing and Synchronization — As 5G has more stringent timing requirements, it is important to ensure all network elements are synchronized with the correct time of day, frequency and phase. This requires either a quick check of the 1588 PTP protocol, to ensure a valid link to the grand master (GM), or an advanced test to ensure proper timing accuracy with time error (TE). The 5GPro Spectrum Analyzer is part of the comprehensive FTB 5GPro test kit with easy to configure 1588 PTP and TE testing and a high accuracy GNSS receiver (see ***Figure 3***). EXFO's best-in-class timing and synchronization helps operators save some 90 percent in troubleshooting time.

RF Spectrum Analysis Over CPRI — With 5G NSA, RF spectrum analysis over CPRI is used to analyze the 4G uplinks that are the anchors of the 5G downlinks. Any passive intermodulation (PIM) or interference on the 4G uplink must be resolved because of the impact on the quality of the 5G communication. EXFO's iORF provides an intelligent and automated way to perform RF spectrum analysis over CPRI, enabling users with any skill level to detect external or internal RF interference or PIM in less than two minutes. If the issue is external, the user can switch from the iORF application to the 5GPro Spectrum Analyzer to hunt for the interferer.

SINGLE, COMPLETE TEST SOLUTION

EXFO's 5GPro Spectrum Analyzer is available on the FTB 5GPro test kit for a complete all-in-one solution to validate 4G and 5G networks. In addition to sub-6 GHz and mmWave spectrum testing, the FTB 5GPro supports fiber inspection and characterization, CPRI, eCPRI, O-RAN, RF spectrum analysis over CPRI, up to 100G Ethernet, timing and synchronization. This comprehensive solution reduces the number of devices field technicians need to carry, speeding jobs and reducing the total cost of ownership for operators and contractors.

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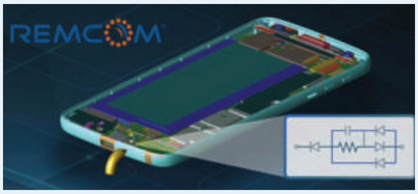
Transient EM/Circuit Co-Simulation Improves ESD Protection



Remcom has updated XFdtd® 3D EM Simulation Software with transient electromagnetic (EM)/circuit co-simulation for electrostatic discharge (ESD) testing, adding support for transient voltage suppressor (TVS) diodes and spark gaps. The new capability helps engineers reduce costly ESD testing of hardware prototypes and eliminate certification setbacks in their device designs.

XFdtd has several tools for simulating ESD testing that reveal components susceptible to ESD damage, thus optimizing ESD mitigation and preventing trial-and-error testing on a physical prototype. The updated software will import TVS diode netlist files and include the diode's nonlinear behavior in a finite-difference time-domain simulation. TVS diodes are used to protect circuits from the surge voltages of an ESD event. They are commonly placed along input/output lines, audio hardware, human interface devices, power supplies and the RF front-end of an antenna. While widely used, TVS diodes have been challenging to simulate in full-wave EM and circuit solvers.

Remcom's transient EM/circuit co-simulation combines a transient nonlinear circuit solver with a full-wave EM solver. To enhance accuracy, XFdtd simulates non-destructive testing using a virtual prototype of the physical layout of the TVS components, simultaneously capturing all EM phenomena from the 3D CAD geometry and the complex nonlinear behavior of the circuit model in a single time-domain simulation. Various diode placements can be simulated to optimize the circuit layout and increase the ESD protection of the final design. XFdtd overcomes the limitations of specialized solvers used individually, enabling engineers to analyze device protection measures more efficiently and effectively. By resolving ESD vulnerabilities before committing to prototype hardware, certification setbacks are avoided.

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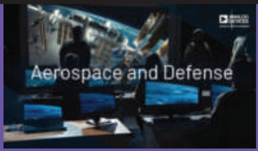

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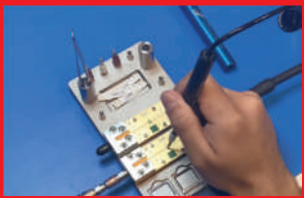

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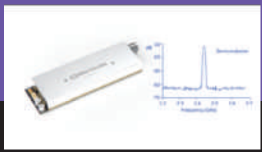

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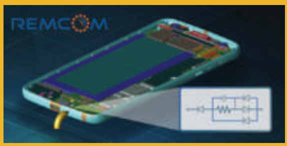

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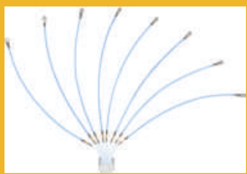
https://mpd.southwestmicrowave.com/product-category/end-launch-connectors/

Capability ConvergeRF Spliced Cable Assembly in Application Note

SV Microwave's ConvergeRF cable assemblies transition seamlessly from Ø.086" to Ø.047" cable types through a direct solder connection maximizing routing capability in a tight space while maintaining low insertion loss.

SV Microwave
https://bit.ly/2UMy60M



NEW PRODUCTS

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

COMPONENTS

Bandpass Filters

VENDORVIEW

Atlanta Micro introduces 3 passive bandpass filters implemented on chip that provide low loss and high rejection in miniature packages. These filters are useful as an IF filter in any RF system for image, LO and spur rejection. All 3 are AC coupled and matched to 50 ohms and operate over the -40°C to +100°C temperature range. AM3056 features 1 GHz center frequency, 500 MHz bandwidth and 5 mm QFN AM3055 features 2 GHz center frequency, 1 GHz bandwidth and 5 mm QFN. AM3188 features 3 GHz center frequency, 1 GHz bandwidth and 4 mm QFN.

Atlanta Micro
www.atlantamicro.com

Programmable Attenuators

New programmable attenuators – standard frequency models are available covering 10 MHz to 21 GHz and provide either 31.5 or 63 dB of attenuation over the full frequency range. Units are fully programmable by the user. Model MLAT-1000A 10 MHz to 21 GHz / 31.5 dB attenuation, Model MLAT-1000B 10 MHz to 21 GHz / 63 dB attenuation. Applications include wideband receivers, automated test systems, telecom, satcom, UAVs and drones and a variety of military and commercial test applications.

Micro Lambda Wireless
www.microlambdawireless.com

Three-Way Splitter/Combiner

VENDORVIEW

Mini-Circuits' model ZC3PD-V24443+ is a 0° DC-pass three-way power splitter/combiner for applications from 24 to 44 GHz. The RoHS-compliant power splitter/combiner provides typical isolation of 32 dB between ports across the full frequency range. Typical full-band insertion loss (above the 4.8 dB three-way power division loss) is 1.2 dB. Full-band VSWR at all ports is typically 1.14:1 or better. The three-way power splitter/combiner maintains low phase unbalance of typically 3.1 deg across the full bandwidth with excellent amplitude unbalance of typically 0.25 dB.

Mini-Circuits
www.minicircuits.com

Transformer Sets

VENDORVIEW

Features broadband >18 dB return loss <1.5 dB IL loss with phase and amplitude match for 75 ohm RF high powered wideband signals. MiniRF offers the MRFXF0086 transformer in a std .250 × .280 SMD package. Designed to operate over temperature range of -40°C to 85°C with minimal variation. It is ideal for output balanced amplifier circuit applications transforming high impedance amplifiers to 75 ohms. Contact MiniRF for samples.

MiniRF
www.minirf.com

Hybrid Coupler

VENDORVIEW

PMI Model No. QC-5010-NFF is a hybrid coupler that operates over the 5 to 10 GHz frequency range. It has a maximum insertion loss of 1.1 dB and a minimum isolation of 16 dB. This model is outfitted with N female connectors in a housing measuring 1.870" × 1.315" × 0.787".

Planar Monolithics Industries
www.pmi-rf.com

K-Band Waveguide Components

VENDORVIEW

Smiths Interconnect launched its broad range of K-Band waveguide components for satellite communication payloads in GEO/MEO and LEO orbits. Highly compact and ruggedized, Smiths Interconnect's K-Band waveguide components are rigorously qualified for spacecraft use in the company's state-of-the-art test and qualification laboratory in Dundee, Scotland. Qualification for spacecraft use is completed for each product and comprises sine and random vibration, mechanical shock and where appropriate RF power TVAC, average power and multipaction, and critical power testing. Summary and qualification data reports are available to prospective customers.

Smiths Interconnect
www.smithsinterconnect.com

Precision Resistors

With electric mobility, the demand for electronic precision components is growing. In these applications, high precision and reliability are paramount. Chip resistors in thin-film technology meet these requirements in an ideal way. With its RG series, certified according to the automotive standard for passive components AEC-Q200, the Japanese manufacturer Susumu Co., Ltd. meets these requirements. Available for nominal power ratings from 0.03 to 0.25 W, these resistors can be used in a wide temperature range from -55°C to +155°C.

Susumu Deutschland GmbH
www.susumu.de

CABLES & CONNECTORS

Waveguide Contactless Flange

VENDORVIEW

Eravant's patent-pending Proxi-Flange™ (STQ-WG-05025-FB-CF) is constructed with a special waveguide flange populated with an array of small pin-like structures to realize the RF choking actions. The Proxi-Flange™ avoids the problem of poor return loss and high insertion loss caused by imperfect contact when two waveguide flanges are mated. The captive screws normally used in waveguide test sets can cause cocking issues if tightened unevenly, but Proxi-Flange™ eliminates the need for any waveguide screws, resulting in improved durability, measurement consistency and repeatability.

Eravant
www.eravant.com

SUCOFLEX® 550 Cable

The new SUCOFLEX 550 cable from HUBER+SUHNER raises test and measurement applications to the next level of precision and reliability. This customisable solution boasts excellent reliability over an extended service life, providing industry professionals with an assembly that minimizes testing downtime and delivers excellent price-performance ratio. The HUBER+SUHNER high performance cable assembly SUCOFLEX®550 is suitable for up to 50 GHz, provides excellent return loss, phase and amplitude stability compared to bending as well as low loss.

HUBER+SUHNER AG
hubersuhner.com

NewProducts

SMPM Blocks

Samtec recently released ganged, multi-position dual-row and single-row SMPM blocks (GPPB Series). The dual-row design includes eight SMPM receptacles per row with surface-mount board connection. The single-row design includes two or eight SMPM receptacles with edge-mount board connection. Pitch options include 5.08 mm (.200”), 8.33 mm (.328”) or custom solutions.

Samtec
samtec.com

AMPLIFIERS

Exodus AMP2085E

VENDORVIEW

Exodus AMP2085E-LC, a rugged quiet broadband class A/AB design for all industry applications. Frequency 2 to 8 GHz, 400 W minimum, 500 W typical, 57 dB gain, unprecedented performance. Excellent power/gain flatness as compared to other amplifiers. Forward/Reflected power monitoring, VSWR, voltage/current/temperature sensing for superb reliability and ruggedness. The nominal weight is 55 kg in a compact 7U chassis 12.25”H × 19”W × 27”D.

Exodus Advanced Communications
www.exoduscomm.com

Low Noise Amplifiers

VENDORVIEW

Fairview Microwave Inc. has unveiled a new series of low noise amplifiers (LNAs) that are perfect for use in electronic warfare, radar, space systems, R&D, prototype/proof of concept, ECM, microwave radio, VSAT, SATCOM, and test & measurement applications. Fairview Microwave’s new series of input protected LNAs feature GaN semiconductor technology which provides robust input power protection. GaN semiconductors ensure state-of-the-art performance with excellent power-to-volume ratio that is ideal for broadband high-power applications.

Fairview Microwave Inc.
www.fairviewmicrowave.com

Broadband GaN Power Amplifier

VENDORVIEW

Inspower Model INS3037 is a high power, class AB, GaN amplifier that operates from 700 to 2700 MHz. It provides a saturated output power of 100 Watt minimum with a power gain of 50 dB minimum. This PA operates from an input DC voltage of 26-30 VDC. Module size is 230 × 120 × 25 mm and is available in a module only or integrated with a heat sink. This is an inspower standard amplifier, usually in stock and can be shipped with short lead times.

Inspower co. ltd.
www.inspower.co.kr

SOURCES

Indirect Synthesizers

Kratos General Microwave enhanced its series of fast switching (1 μsec) indirect synthesizers with the addition of the Model SM6220 with frequency modulation capability covering the full band 2 to 20 GHz. It can provide a frequency deviation of 1 GHz at up to a 10 MHz modulation rate and can be modulated with either analog or digital inputs. Of special significance; the synthesizer output frequency remains fully locked even while in the FM mode.

Kratos General Microwave
www.kratosmed.com

SOFTWARE

MACOM GaN Library

VENDORVIEW

Modelithics Inc. and MACOM announced the first release of the new Modelithics MACOM GaN Library. The models in the Modelithics MACOM GaN Library will be offered for FREE distribution and support for qualified MACOM customers. The initial release of the Modelithics MACOM GaN Library v21.1.0 includes highly accurate non-linear models for MACOM PURE CARBIDE™ devices.

Modelithics Inc.
www.Modelithics.com

ANTENNAS

Phased Array Antenna Innovator Kits

VENDORVIEW

Anokiwave Inc. announced the introduction of the first in a family of a complete mmWave to IF phased array antenna innovator kits to assist 5G equipment manufacturers to easily evaluate array level performance of Anokiwave's ICs, develop new mmWave 5G NR radio front ends and to utilize this platform to accelerate their radio developments. The new AWA-0213-PAK is 28 GHz band (n257/n261) active antenna built upon Anokiwave's 3rd generation silicon ICs and features the performance of the company's patented Zero-Cal® at an array level.

Anokiwave Inc.
www.anokiwave.com

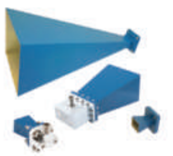
3-Axis mmWave and THz Antenna Positioner

GIM04 is MilliBox's latest generation of mmWave and THz positioners. It can control 3 axes of rotation in elevation, azimuth and polarization from a single USB controller. Its construction allows GIM04 to adjust to various DUT form factors. GIM04 adds a new level of versatility for daily over-the-air measurements.

MilliBox
www.millibox.com

Waveguide Horn Antennas

VENDORVIEW



Pasternack has launched a new series of standard gain waveguide horn antennas to address a wide range of R&D, test and measurement, government/military, wireless communication and microwave radio systems applications. Pasternack's new waveguide horn antennas can be used in a broad variety of applications due to their high-power handling capability, low loss, high directivity and near constant electrical performance. These standard gain waveguide horn antennas are available in a wide range of gain options, frequency support and sizes.

Pasternack
www.pasternack.com

MICRO-ADS

New**Products**

Multiband Antenna Booster

The ONE mXTEND is the smallest Virtual Antenna™ supporting cellular and unlicensed IoT wireless devices. It is part of a new generation of antenna solutions based on Ignion's Virtual Antenna technology. This technology enables replacing conventional and custom antenna solutions with a new class of antenna boosters, including miniature and off-the-shelf chip antenna components. These new multiband, multipurpose chip antennas fit in a variety of wireless platforms. This enables simpler, faster and less expensive designs versus custom solutions.
Richardson RFPD
www.richardsonrfpd.com

TEST & MEASUREMENT

Automatic Calibration Module

ACM2708 is an automatic calibration module that can be used with CMT Vector Network Analyzers operating in frequency range up to 8 GHz. The ACM 2708 is a 75 Ohm calibration module for use with native 75 Ohm VNAs (S7530) while also covering automatic calibration for 50 Ohm VNAs with the use of 50 to 75 Ohm matching pads. It is a fully automatic USB-controlled and powered electronic calibration module. Minimizing the number of steps required by technicians reduces the risk of human error and expedites the calibration process.
Copper Mountain Technologies
www.coppermountaintech.com

5GPro Spectrum Analyzer

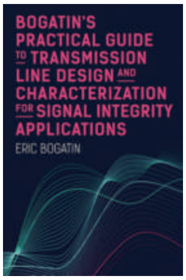
The 5GPro Spectrum Analyzer's revolutionary FR1 and FR2 testing modules deliver optimal scalability on a single platform for extreme flexibility and scalability. Field upgradeable design means no downtime due to factory upgrades. A smart UX-optimized GUI simplifies RF testing, enabling field techs to do more in less time. A complete solution, it supports RTSA bandwidth up to 100 MHz, 5G NR demodulation and beamforming analysis, TDD and LTE signal analysis. Available now on the FTB 5GPro.
EXFO
www.exfo.com

Butler Matrix

MIcable SA-07-4B006050 is a 0.6 to 5 GHz 4x4 butler matrix which can transfer the signal reciprocally from any of 4 ports to any of other 4 ports. It covers 5G NR (FR1) frequency band and has high versatility for 5G NR test applications. Because the high performance passive components and cables are used inside, the system has super phase accuracy, amplitude balance, stability and repeatability.
Fujian MIcable Electronic Technology Group Co. Ltd.
www.micable.cn

Microwave/RF Test Assemblies

Designed for test applications that depend on accurate, repeatable measurements, W. L. Gore & Associates offers GORE® PHASEFLEX® Microwave/RF Test Assemblies, which provide excellent mechanical durability and electrical performance. Gore's RF cable assemblies not only feature a rugged construction that prolongs service life, but they also offer high phase and amplitude stability for high-density and modular test applications at an affordable price.
W. L. Gore & Associates
www.gore.com



Bogatin's Practical Guide to Transmission Line Design and Characterization for Signal Integrity Applications

Eric Bogatin

This multimedia eBook establishes a solid foundation in the essential principles of how signals interact with transmission lines, how the physical design of interconnects affects transmission line properties and how to interpret single-ended and differential time domain reflection measurements to extract important figures of merits and avoid common mistakes. This book presents an intuitive understanding of transmission lines.

Instructional videos are provided in every chapter that cover important aspects of the interconnect design and characterization process. This video eBook helps establish foundations for designing and characterizing the electrical properties of interconnects to explain in a simplified way how signals propagate and interact with interconnects and how the physical design of transmission structures will impact performance.

Never be intimidated by impedance or differential pairs again.

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5G

Eravant: Renewing Itself for the Journey to 1 THz

Eravant has been renewing itself since Wendy Shu became CEO in 2019, taking the management reins from her father Yonghui. He formed the company with his wife in 2011 and still provides the technical leadership for the company. While the founding commitment to commercialize mmWave technology through technical leadership and great products has not changed, Wendy has focused on the culture, processes and facilities that will enable Eravant to sustain its growth and reputation for responsiveness. Her mission is to move the company from the "start-up" phase through the "grow up" phase.

Eravant's renewal began with a name change, from SAGE Millimeter to Eravant. "Era" reflects a new beginning and "vant" comes from the word "savant," a choice that honors prior brands WiseWave and SAGE Millimeter and conveys deep respect for learning and capability. The name and the values it reflects were intended to communicate internally as much as to customers, as a way to reinforce Eravant's culture. As a company grows, the founders must delegate much of the responsibility and authority, trusting the culture will guide "the way we behave when no one is watching" and the many decisions made each day.

Another sign of Eravant's renewal is its renovated facility, a 60,000 square foot build-out containing agile workstations, an ISO 8 clean room, two anechoic test chambers and a high performance lab capable of vector network analyzer measurements to 330 GHz, noise figure to 170 GHz and power to 1 THz. As much as being functional, the aesthetic was designed to inspire creativity and personal renewal, seen in the natural light, a library, indoor-outdoor café staffed by a barista and a basketball court. The basketball court is named "The Mamba Court" to honor local basketball legend Kobe Bryant.

Eravant's mission is enabling future technology, which is rapidly extending beyond mmWave to THz. The new facility will support the company's growth from its base of more than 4,000 products spanning virtually all mmWave active and passive circuit functions, as well as test equipment. The test equipment portfolio includes Doppler radar target simulators and numerous frequency extenders for vector and scalar network analyzers and noise figure measurements. Eravant also offers waveguide calibration kits, noise sources and cost-effective ANSI/NCSL compliant calibration services for power meters and sensors and plans to add environmental test capabilities like shock/vibration and thermal vacuum testing.

With such a large product catalog, Eravant can quickly respond to custom requirements to 330 GHz, whether shifting the frequency band of an existing product or integrating multiple components into a subsystem. Attentive to market trends, Eravant has responded to the investment in low Earth orbit satellite constellations for broadband, IoT and imaging services by helping define industry standards for "commercial" satellite applications. Many of its products are already "space ready" because of the intentional mechanical design and materials used.

With its expanded facility and cumulative shipments now in the hundreds of thousands—some products flying in space—Eravant has a repeatable manufacturing capability with capacity to support production for most any test and measurement, communications, radar, scientific or space application. Its network of established manufacturing partners can support the ramp to volume production.

Following the new name and new facility, Eravant's renewal continues. Wendy Shu says, "Happiness and a purposeful life are achieved through the pursuit of potential." Eravant is pursuing its potential, looking to 1 THz for a new generation of leadership products, designed and built in a culture that will provide purposeful and fulfilling work for its growing team.

www.eravant.com

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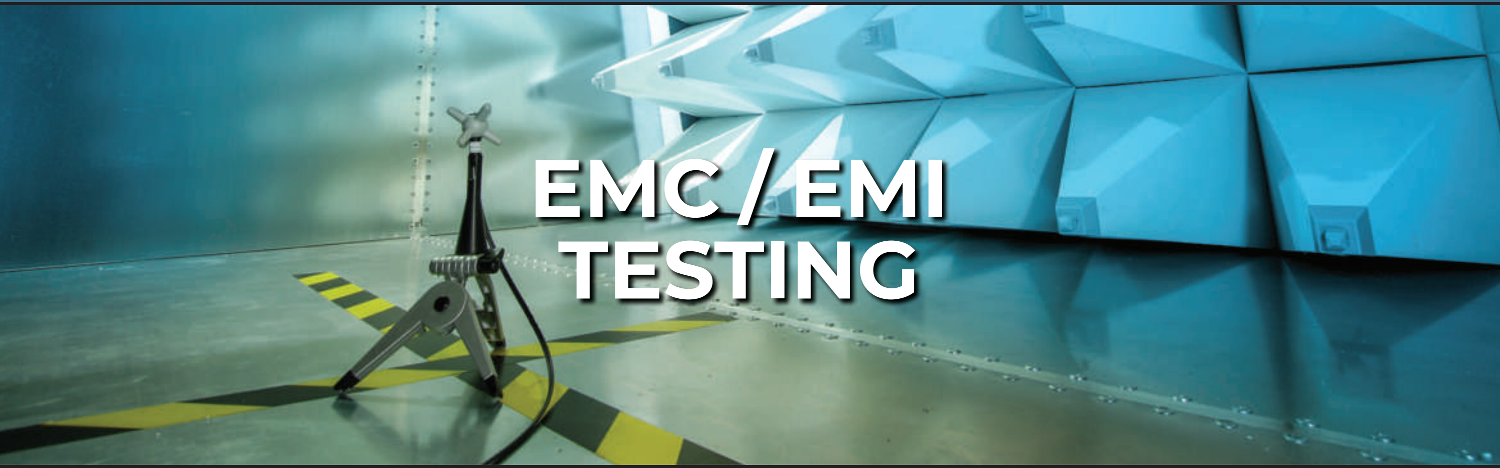

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Model	Type	Frequency (MHz)	Power (W CW)	Coupling (dB)	Insertion Loss (dB)	Connectors	Size (inches)
C8730	Dual	0.009-250	500	40	0.40	N-Female	10.5 x 3.0 x 2.0
C8731	Dual	0.009-250	1000	40	0.40	N-Female	10.5 x 3.0 x 2.0
C11462	Dual	0.009-400	500	40	0.45	N-Female	6.7 x 2.28 x 1.69
C8510	Dual	0.009-1000	500	40	0.45	N-Female	6.7 x 2.28 x 1.69
C5047	Dual	0.01-100	4,000	50	0.15	7/16-Female	10.0 x 4.16 x 3.5
C1979	Dual	0.01-100	10,000	60	0.10	LC-Female	2.0 x 6.0 x 4.5
C5086	Dual	0.01-250	250	40	0.50	N-Female	5.2 x 2.67 x 1.69
C5100	Dual	0.01-250	500	40	0.40	N-Female	10.5 x 3.0 x 2.0
C5960	Dual	0.01-250	1,000	50	0.40	N-Female	10.5 x 3.0 x 2.0
C1460	Dual	0.01-250	2,000	50	0.15	N-Female	10.0 x 3.0 x 2.0
C4080	Dual	0.01-250	3,500	50	0.20	N-Female	10.0 x 4.6 x 3.5
C11026	Dual	0.01-220	5,000	60	0.10	LC-Female	12.0 x 6.0 x 4.5
C8390	Dual	0.01-250	10,000	60	0.10	LC-Female	12.0 x 6.0 x 4.5
C5339	Dual	0.01-400	200	40	0.50	N-Female	5.2 x 2.67 x 1.69
C6047	Dual	0.01-400	500	40	0.50	N-Female	5.2 x 2.67 x 1.69
C2630	Dual	0.01-1000	100	40	0.60	N-Female	5.0 x 2.0 x 1.51
C6021	Dual	0.01-1000	500	40	0.45	N-Female	6.7 x 2.28 x 1.69
C6277	Dual	0.01-1000	500	50	0.45	N-Female	6.7 x 2.28 x 1.69
C11146	Dual	0.01-1000	500	43	0.45	SC-Female	6.7 x 2.63 x 2.20
C11047	Dual	0.01-1000	1,000	43	0.45	SC-Female	6.7 x 2.63 x 2.20
C11161	Dual	0.01-1000	1,000	50	0.45	SC-Female	6.7 x 2.63 x 2.20
C1795	Dual	0.1-1000	100	40	0.50	N-Female	5.0 x 2.0 x 1.51
C5725	Dual	0.1-1000	500	40	0.50	N-Female	5.2 x 2.28 x 1.69
C11077	Dual	0.1-1000	1,000	43	0.45	SC-Female	6.7 x 2.28 x 1.69
C3910	Dual	80-1000	200	40	0.20	N-Female	3.0 x 3.0 x 1.09
C5982	Dual	80-1000	500	40	0.20	N-Female	3.0 x 3.0 x 1.09
C3908	Dual	80-1000	1,500	50	0.10	7/16-Female	3.0 x 3.0 x 1.59
C6796	Dual	80-1000	5,000	60	0.20	1 5/8” EIA	6.0” Line Section
C8060	Bi	200-6000	200	20	0.40	SMA-Female	1.8 x 1.0 x 0.56
C8000	Bi	600-6000	100	30	1.10	SMA-Female	4.8 x 0.88 x 0.50
C10117	Dual	700-6000	250	40	0.20	N-Female	2.0 x 2.0 x 1.06
C10364	Dual	700-6000	500	50	0.20	7/16-Female	2.15 x 2.0 x 1.36
C10996	Dual	700-6000	700	50	0.20	7/16-Female	2.15 x 2.0 x 1.36
C11555	Dual	700-6000	1,000	50	0.20	7/16-Female	2.15 x 2.0 x 1.36
C10695	Dual	700-6500	500	50	0.20	7/16-Female	2.15 x 2.0 x 1.36


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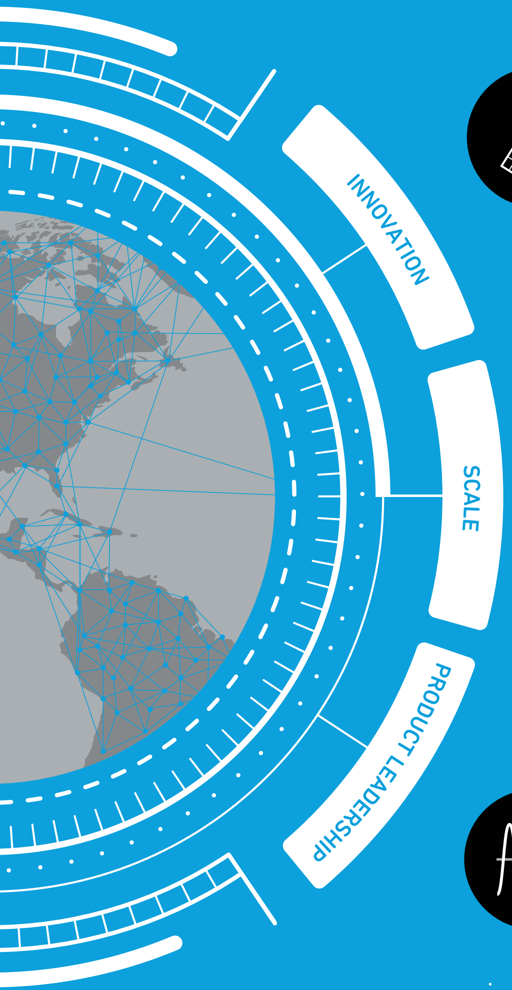

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Description	Freq. Range (GHz)	PAE (%)	Gain (dB)	Part Number
Reconfigurable Dual-band GaN Power Amplifier	X-band (9-11) S-band (3.1-3.5)	X-32, S-47	X-18.5 S-21	QPA0007
10W Transmit/ Receive Module	8-12	32	22 (Tx) 25 (Rx)	QPF5010
GaAs I/Q Mixer	6-26	–	-8	QPX0001
GaN PA (100W)	5-6	47	22	QPA2309
GaAs LNA	6-18	–	27	CMD328K3

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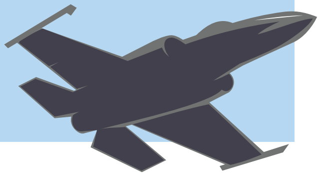
MILITARY & AEROSPACE
TABLE OF CONTENTS



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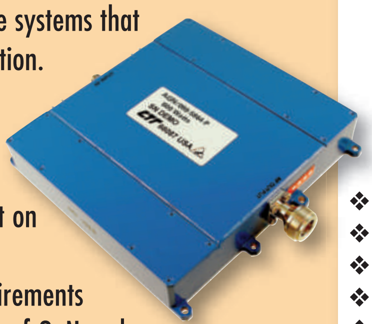

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Accelerating EW System Development, Deployment and Sustainment

Kelsey Ryon
Mercury Systems, Inc., Andover, Mass.

Advances in RF/microwave technologies are driving new capabilities for the armed forces, such as more accurate radars, broadband communication and effective radar deception. However, emerging adversarial threats are challenging the ability to apply these tools across a contested electromagnetic spectrum. Whether using artificial intelligence to better identify radar images generated by digital RF memory (DRFM) or deploying advanced electronic intelligence capabilities, adversaries are pushing the limits of existing spectrum processing systems.

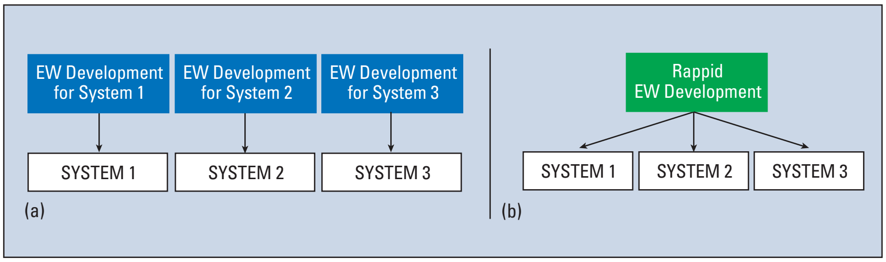
Leveraging the latest commercial technologies while efficiently developing, deploying and sustaining new capabilities is key to maintaining spectrum dominance. In the traditional approach, custom hardware systems run application-specific firmware and software. These "black box" systems have a lengthy development cycle and are difficult to upgrade with the latest technology. To remain competitive, new capabilities must be fielded faster.

This need led to an increased focus around how open architecture systems are built and maintained. Through standards such as OpenVPX™ and SOSA™, off-the-shelf hardware is relatively quickly and easily incorporated into new electronic warfare (EW) systems, shortening the development cycle and simplifying upgrades. These open hardware modules include microwave transceivers, digitizers, field-programmable gate array (FPGA) processors, single-board computers and network switches. However, without standards for the software and firmware, the EW techniques remain tightly coupled to the hardware implementation, reducing the ability to fully take advantage of open hardware standards.

OPEN HARDWARE, OPEN FIRMWARE, OPEN SOFTWARE

The key to a fully open spectrum processing platform is the ability to integrate open hardware, open firmware and open software. Through this holistic approach, the hardware is decoupled from the application-specific software and firmware, minimizing the need to customize an application for a specific hardware implementation.

In the case of EW, this approach is vital to accelerating all stages of the system lifecycle. In the development phase, a system can be prototyped on a standard development chassis. By leveraging commercial off-the-shelf (COTS) hardware and a library of software and firmware design blocks, development time is greatly reduced. In the deployment phase, the open framework allows the EW techniques, in the form of a heterogeneous firmware/software application, to be easily migrated from one hardware set to another. Finally, in the sustainment phase, system updates are made by updating discrete system elements without a full redesign.



▲ Fig. 1 Traditional EW development model (a) vs. the Rappid spectrum processing platform (b).

While there are open hardware standards and some open software standards, little has been done to standardized FPGA firmware, nor combining open hardware, open firmware and open software together to support heterogeneous processing applications.

A NEW STANDARD FOR OPEN FPGA FIRMWARE

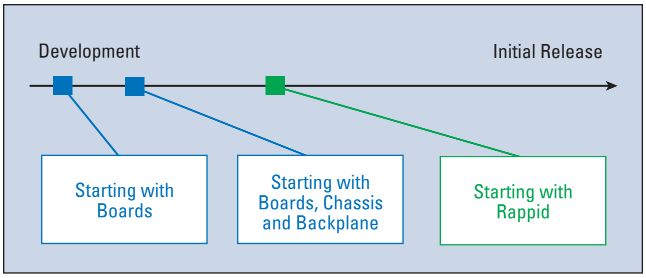
Industry has historically struggled with full FPGA hardware abstraction, since there is little room for an abstraction layer without severely impacting processing efficiency. However, a partial abstraction focused on spectrum processing applications can provide standardization without the overhead of a full hardware abstraction.

As a significant step toward full FPGA hardware abstraction, Mercury Systems has developed OpenFPGA™, an open framework that enables FPGA firmware applications to be ported from one hardware set to another. OpenFPGA works by taking hardware devices and board support packages and adding a thin wrapper to expose common input, output, command and status interfaces for FPGA resources. This partial FPGA abstraction adds flexibility to deployed systems while minimizing processing overhead.

The OpenFPGA framework enables algorithms—EW techniques, software-defined radio (SDR) and others—to be easily loaded into different spectrum processing systems without making in-depth changes or customizing the algorithms. If the algorithms are compliant with OpenFPGA, the development and deployment of these capabilities are straightforward across disparate subsystems. The OpenFPGA framework provides several benefits to the development, deployment and sustainment aspects of a program, while moving away from solutions tied to specific suppliers. OpenFPGA solutions are rapidly implemented, regardless of the FPGA hardware, and smoothly ported to any hardware device supporting OpenFPGA (see ***Figure 1***).

This architecture simplifies mission application development and provides a hardware-agnostic approach to developing applications. For example, the ability to use the same hardware for different missions opens the possibility of using the hardware as a DRFM jammer, later as a GPS receiver or SDR by reprogramming and executing a different mission application.

Integrating OpenFPGA firmware with existing open hardware and open



▲ Fig. 2 Rappid processing platform reduces development time.

software standards delivers a fully open platform that accelerates the delivery of the latest microwave technologies and spectrum processing techniques where they are needed most. As new EW techniques become available, they can be ported from a development chassis to multiple tactical systems. As new hardware becomes available, the systems can be upgraded without major changes to the software and firmware applications. Additionally, by decoupling the hardware from the algorithms, third-party developers can design applications to run on various hardware platforms, increasing the capabilities of spectrum processing systems.

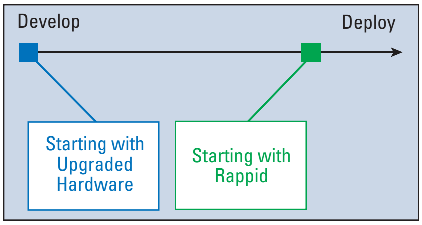
THE RAPPID™ SPECTRUM PROCESSING PLATFORM

To deliver these benefits, Mercury Systems has developed the Rappid spectrum processing platform. Rappid combines open hardware, open firmware and open software to provide new options for how spectrum processing systems are developed, deployed and sustained. To demonstrate the power of this approach, compare a handheld GPS receiver to a smartphone. In the handheld GPS receiver, the software/firmware applications are specific to the hardware, and updates are limited and controlled by the hardware manufacturer. With a smartphone, new applications are easily deployed to different hardware implementations, maximizing flexibility and capability.

The Rappid platform consists of the OpenFPGA framework as well as open hardware and open software. The open hardware component includes standards such as SOSA and OpenVPX, and the open software layer adopts existing industry standards to create a solution for multi-mission application development. Integrating technologies such as Docker, OpenDDS, gRPC and hardware-agnostic drivers enable applications to be quickly developed in software and used across many different systems. This flexibility with software and firmware development enables a "develop one, deploy anywhere" solution for application development.

Traditional spectrum processing system design is complex and lengthy. Rappid shortens design time by enabling the developer to bypass steps such as designing custom boards, defining the data/command interconnections and porting custom IP (see ***Figure 2***). Rappid has support software and firmware in the form of device drivers, OpenFPGA, remote programmability and function libraries (i.e., middleware) so system developers can focus on designing and implementing proprietary mission applications.

To reduce costs and further improve timelines, Rappid hardware supports COTS modules from multiple industry-



▲ Fig. 3 Rappid also simplifies EW system sustainment, enabling new hardware to run existing applications.

trusted suppliers—the same hardware that primes and government customers are familiar with and trust. The abstraction capabilities of Rappid provide a seamless deployment of applications from the lab to the prototype and then fielded solutions (see ***Figure 3***). Rappid provides a level of abstraction from the hardware for both software and firmware, which simplifies system sustainment and enables new hardware to run existing applications. New development only requires application upgrades to access the new hardware capabilities. By leveraging commercial products from trusted companies, the Rappid platform mitigates the risk of component obsolescence.

MAXIMIZING EW SYSTEM PERFORMANCE

Traditional EW systems support a predefined set of low latency capabilities designed into FPGAs. If a more extensive set of capabilities is required, the system designer must either increase the number of FPGAs or increase the size of the FPGA. Both options are costly and increase the physical size of the system and associated thermal dissipation challenges. Using the Rappid open platform, EW techniques can be dynamically swapped in and out of memory as needed, maximizing system performance without the need for expensive, large and hard-to-cool FPGAs.

Supporting the Rappid platform, many heterogeneous applications are available to reduce system development time. These optional add-ons consist of FPGA firmware and CPU software applications. Rappid enables designers to use these preconfigured and pretested applications as building blocks to accelerate system prototypes and solutions. This library of commonly used algorithms reduces the development effort so designers can spend more time on developing proprietary IP to transform baseline subsystems into unique system solutions.

SUMMARY

The ability to rapidly develop and deploy high performance systems is critically important to maintain control of the electromagnetic spectrum. By integrating open firmware standards, open software and open hardware, the Rappid platform provides a starting point for new system designs, jump starting the traditional approach by standardizing the system infrastructure. Systems tailored to specific applications built using this new framework will have dramatically shorter design time. Rappid enables new, innovative ways to apply scalable and standardized technology to the tough spectrum processing challenges, yielding greater flexibility, accessibility and sustainability. ■

Kelsey Ryon is a product marketing manager for Mercury Systems' mixed signal group. Ryon has more than a decade of experience in infrastructure and GIS systems and has developed insights into the global businesses. She earned a Bachelor of Science degree from Athens State University.

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Architecture of the Cospas-Sarsat Global Satellite Distress and Safety System for Military Applications

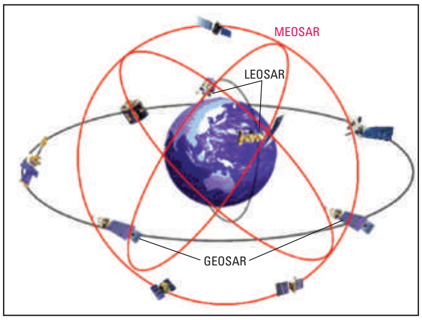
Dimov Stojce Ilcev
Durban University of Technology, Durban, South Africa

This article describes the global international Cospas-Sarsat satellite distress and safety system (SDSS) integrated with low earth orbit (LEO), medium earth orbit (MEO) and geostationary (GEO) satellite constellations that provides services at sea, on land and in the air. The Cospas-Sarsat space segment integrated with the near-polar LEO constellation is known as the LEOSAR subsystem, the space segment integrated with the MEO is known as the MEOSAR subsystem and the space segment integrated with the GEO constellation is known as the GEOSAR subsystem. Similarly, the Cospas-Sarsat ground segment consists of local user terminal (LUT) stations, known as the LEOLUT, MEOLUT and GEOLUT subsystems, and the associated regional Mission Control Centers (MCC) connected with the Rescue Coordination Center (RCC) and local Search and Rescue (SAR) infrastructures. This article also reviews satellite repeaters providing SDSS service via satellite beacons known as emergency position indicating radio beacons (EPIRBs) for maritime, personal locator beacons (PLBs) for land, personal and emergency locator transmitters (ELTs) for aeronautical applications. In addition, types of satellite beacons and testers, LUT receivers with antennas, the Cospas-Sarsat Data Distribution Plan and the Alert Data Distribution and Operating System are described.

Oceangoing ships are sinking or disappearing, airplanes are crashing in disasters without a trace, land vehicles and expeditions are being lost in the wild and other causal emergencies are emerging that threaten many lives and property at sea, in the vast inner landscape and airspace around the world. The constant advancement of technology and the extremely improved use of radio have historically been the goal of those in charge of solving the problem of SAR at sea, on land and in the air. In the early history of mobile radio, only 120 years ago, radio stations were installed on ships to improve the safety of life and property at sea.

Although these improvements started well and helped save many lives and assets, they were not effective enough in the event of a sudden, catastrophic loss of a carrier platform. The most effective improvements occurred at the

▲ Fig. 1 Initial Cospas-Sarsat emblem. *Source:* Cospas-Sarsat.



▲ Fig. 2 Cospas-Sarsat satellite constellation.

end of the previous century with the improvement of safety of life at sea using MF/HF and very high frequency (VHF) radio and the recent development of safety systems, such as the integration of a new digital selective call (DSC) radio integrated with Cospas-Sarsat and Inmarsat satellite systems. These new integrations, known as the Global Maritime Distress and Safety System (GMDSS) developed by the International Maritime Organization and the Future Air Navigation System (FANS) of the International Civil Aviation Organization (ICAO), can be used to improve safety and security at sea and in the air.

In 1999, the author of this article invented a better Global Aeronautical Distress and Safety System (GADSS) than the still not fully operational "long way" program of ICAO's FANS. Since 2005, he has published chapters on GADSS, and in 2020, Springer published his book on GADSS Theory and Applications.

ORGANIZATION AND SIGNATORIES

The Cospas-Sarsat system is a joint international satellite-assisted SAR system established and signed in 1979 under a memorandum of understanding (MoU) among agencies of Canada, France, U.S. and the former USSR (today Russia).

Following the successful completion of the demonstration and evaluation phase begun in September 1982, a second MoU was signed on October 5, 1984, by the Department of National Defense of Canada, the Centre National d'Etudes Spatiales of France, the National Oceanic and Atmospheric Administration (NOAA) of the U.S. and the Ministry of the Merchant Marine (MORFLOT) of the former USSR (Russia). Shortly after, the Cospas-Sarsat system was then declared operational in 1985. Its first emblem is shown in ***Figure 1***.

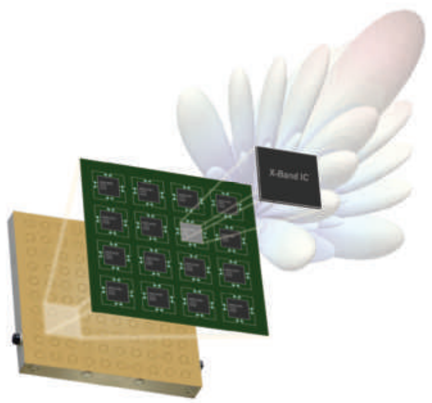
On July 1, 1988, the four states providing the space segment signed the International Cospas-Sarsat Program Agreement, which ensures the continuity of the system and its availability to all states on a non-discriminatory basis. In January 1992, the government of Russia assumed responsibility for the obligations of the former USSR. Several other states, non-parties to the agreement, have also associated themselves with the program and participate in the operation and the management of the system.[1-3]

MISSION AND SERVICE

Initially, Cospas-Sarsat developed the first generation of LEOSAR as a subsegment that employed the two constellations of the polar earth orbit (PEO) and the second generation of the GEOSAR subsegment that deployed the three constellations of GEO satellites. Recently, Cospas-Sarsat and its partners developed the third generation, MEOSAR subsegment, which also uses three constellations.

Figure 2 illustrates the Cospas-Sarsat network of LEOSAR, MEOSAR and GEOSAR satellites. Currently, the LEOSAR subsystem contains five American SARSAT, NOAA and PEO satellites, while the Russian first generation of Cospas satellites are not operational. Russia has launched Meteor-M as new generation of this constellation.

The GEOSAR subsystem contains two Russian Elektro-L and two Louch GEO satellites, two American GOES GEO satellites, two Indian GEO satellites and three MSG GEO satellites of the European Space Agency (ESA). The MEOSAR subsystem contains the ESA Galielo, the U.S. GPA and Russian GLONASS satellite constellations. ***Figure 3*** shows the complete space configuration of the Cospas-Sarsat integrated network containing the GEOSAR, MEOSAR and LEOSAR satellite



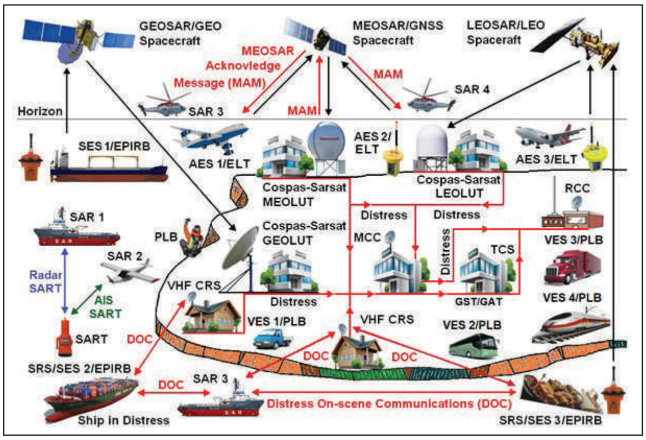


Fig. 3 Cospas-Sarsat mobile aeronautical GEOSAR, MEOSAR and LEOSAR subsystems.

for SAR operations. These new solutions can improve the positioning, tracking and detection of ocean ships and aircraft in emergency situations and facilitate their detection if they are missing or hijacked.

As shown in Figure 3, ship earth stations (SES) with EPIRB, persons and vehicle earth stations with PLB and aircraft earth stations (AES) with ELT in distress

constellations serving all mobile applications. The same figure shows part of the global ship tracking (GST) and global aircraft tracking (GAT) scenarios as important components of the GMDSS and GADSS networks within SAR distress operations, respectively.

The GST and GAT satellite network cannot use Cospas-Sarsat satellites, but ships or aircraft can send tracking messages via Inmarsat or Iridium satellites, tracking control stations and RCC

and emergency situations can be found in the following hypothetical distress situations and SAR operations:

1. Scene I – Ships in distress may manually or automatically activate their EPIRBs and send distress messages via GEOSAR satellite, GEOLUT ground station, MCC and RCC to the ship (SAR) and helicopter (SAR) forces. The EPIRB beacons may also send distress signals via MEOSAR satellites using MEOLUT ground stations and LEOSAR satellites

using LEOSAR ground stations for SAR operations.

2. Scene II – All land vehicles (VES), such as trucks, buses and trains, as well as a person in distress, may manually activate PLBs and send distress messages via GEOSAR, MEOSAR and LEOSAR satellites and ground facilities to SAR forces.

3. Scene III – Aircraft (AES) in distress may manually or automatically activate their ELTs and send distress messages via GEOSAR, MEOSAR and LEOSAR satellites and ground facilities to SAR forces.

4. Scene IV – All ships equipped with a SAR transponder (SART) after activation at sea can be detected by radars onboard SAR ships, aircraft and helicopters for enhanced tracking of the position of ships in distress. It is recommended that aircraft also be equipped with a ship's SART, so that after an emergency landing of an aircraft at sea, they can activate their own SART devices due to their simple identification using SAR radars.

5. Scene V – All ships equipped with an automatic identification system (AIS) SART device after activation at sea can be detected by the AIS receiver onboard SAR ships, aircraft and helicopters for enhanced tracking of the position of ships in distress. In addition, AIS SART or DSC receivers installed onboard SAR units can detect very small special AIS man overboard (MOB) devices mounted on clothing or on lifebelts; which, after activation, enable vessels in the vicinity of a man overboard incident to respond quickly and efficiently to locate and recover a person in the water. It is obvious that these solutions can be used to rescue the crew and passengers after the forced landing of an aircraft on the sea surface.

6. Scene VI – The Cospas-Sarsat service via LEOSAR and GEOSAR satellites is only a one-way transmission of distress signals, while the MEOSAR system enables two-way transmission; namely, it transmits distress signals and receives a confirmation of receipt. In fact, the MEOSAR system provides a special service of MEOSAR Acknowl-

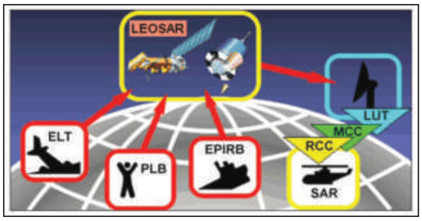


Fig. 4 LEOSAR Cospas-Sarsat system concept. *Source*: Cospas-Sarsat.

edge Message (MAM) sent by a MEOLUT station via a MEOSAR satellite to EPIRB/PLB/ELT terminals (highlighted in red in Figure 4).

7. Scene VII – All ships and aircraft in emergency or distress situations can communicate via their onboard VHF radios and provide distress on-scene communications (DOC) with SAR units. At the same time, all SAR units can use DOC for their mutual communication.[2-5]

SPACE SEGMENT

The Cospas-Sarsat space segment architecture includes three types of satellites to collect and relay emergency messages from the user via the ground segment:

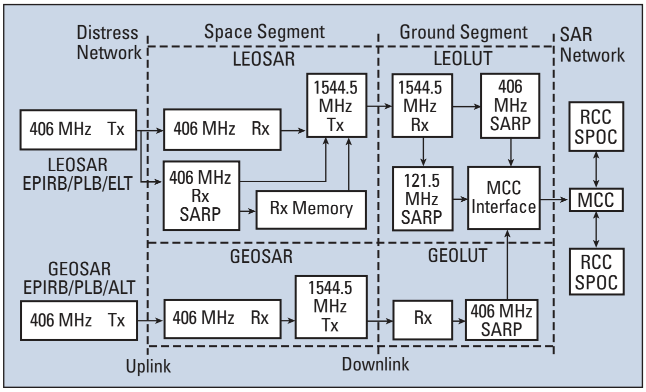
1. Spacecraft in the LEO constellation carry either the Cospas or the Sarsat payload, which is generically referred to as the LEOSAR subsegment. The LEOSAR system is the first designed and it is the longest one in use (see ***Figure 4***). In fact, all radio beacons, such as EPIRB, PLB and ELT, send distress signals via LEOSAR satellites to LEOLUT (LUT) receivers. From there they are sent via MCC and RCC to SAR forces.

2. Spacecraft in GEO constellation carry a SAR payload, generically referred to as the GEOSAR subsegment, which works like the LEOSAR network.

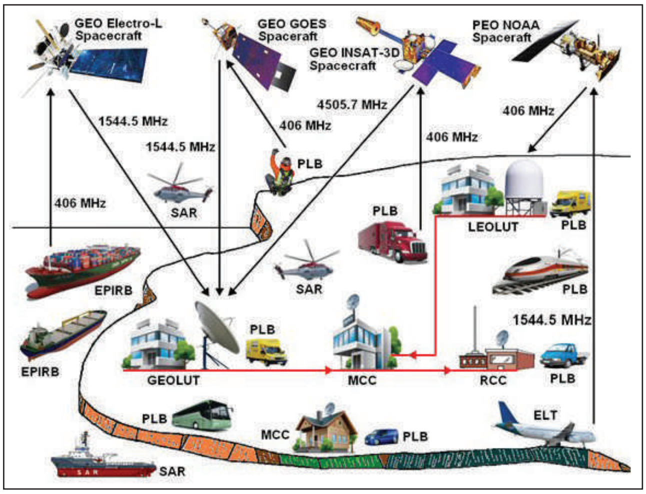
3. Spacecraft in the MEO constellation carry the MEOSAR secondary payload installed on the global navigation satellite system (GNSS), such as the U.S. GPS, Russian GLONASS and European Galileo, which started in 2013 to operate like previous networks.

LEOSAR and GEOSAR Space Segment

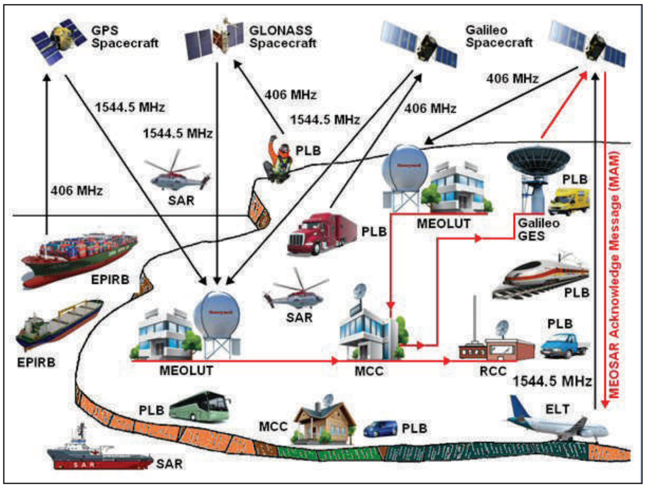
In general, the Cospas-Sarsat LEOSAR and GEOSAR space segment configuration and its relation with the ground segment is shown in ***Figure 5***. The distress alerts sent by LEOSAR or GEOSAR beacons on the ultra-high



▲ Fig. 5 Cospas-Sarsat LEO and GEO system block diagram.



▲ Fig. 6 Cospas-Sarsat LEOSAR and GEOSAR operations.



▲ Fig. 7 MEOSAR operation.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frequency (UHF) of 406 MHz are relayed via the appropriate LEOSAR or GEOSAR satellites to the LEOLUT or GEOLUT ground network subsegment, MCC/RCC, SAR point of contact (SPOC) infrastructures and SAR forces.

Initially, Russia delivered two LEO Cospas satellites placed in near-polar orbits at 1,000 km altitude equipped with SAR instrumentation at 406 MHz. The U.S. delivered two NOAA meteorological satellites of the Sarsat system placed in sun-synchronous polar orbits at about 850 km altitude equipped with SAR instrumentation at 406 MHz, supplied by Canada and France. Each PEO satellite makes a complete orbit of the earth around the poles in about 100 minutes, traveling at a velocity of 7 km/s.

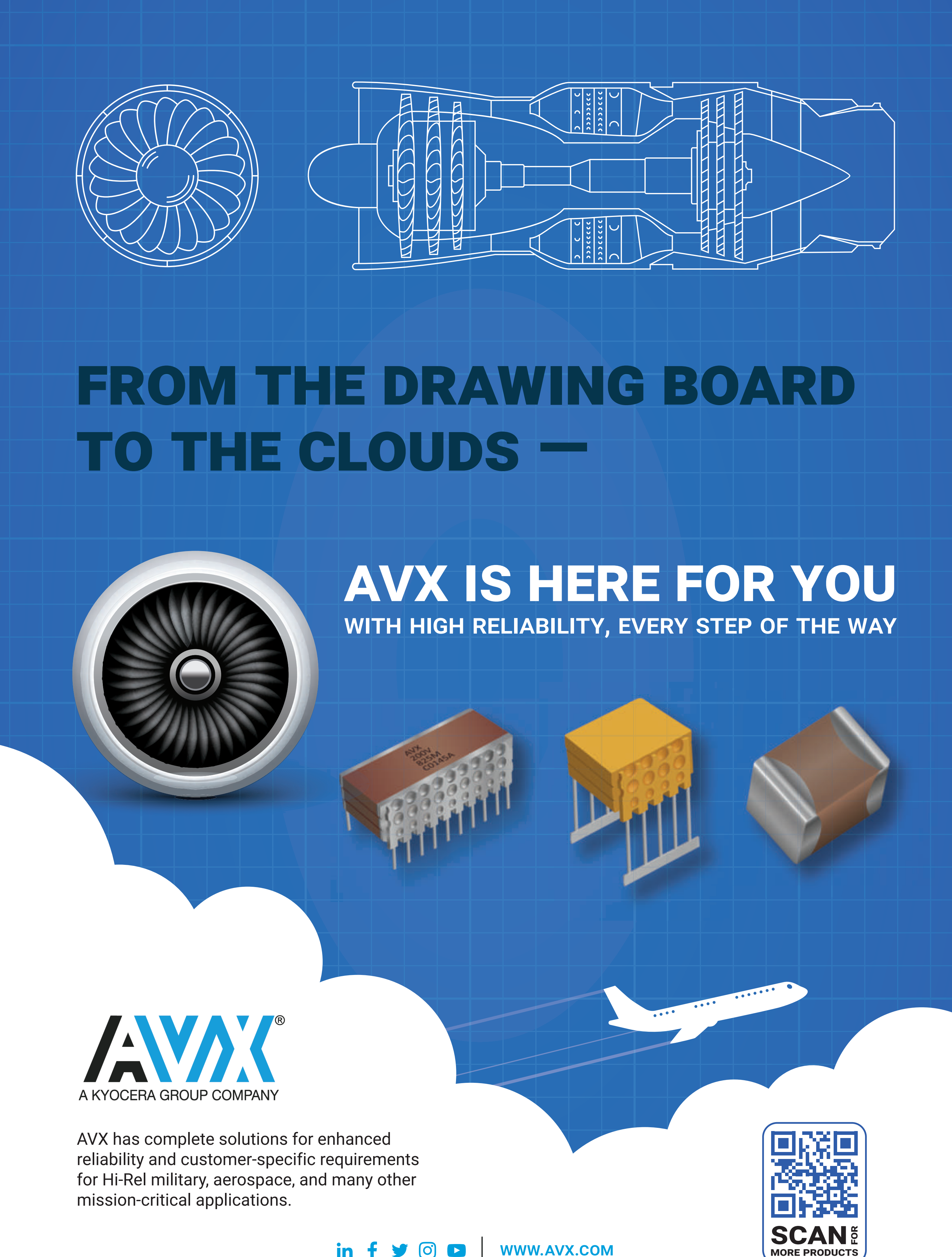
The LEOSAR concept exploits the Doppler shift resulting from relative motion between the distress transmitter and the polar orbiting satellite. A successful alert requires at least one satellite pass over the distress area to detect a signal and locate the position of the emergency transmitter. In some cases, a second pass may be required to resolve ambiguity.

Satellites in the LEOSAR subsegment do not provide continuous coverage. This results in possible delays in the reception of the distress alert. The waiting time for detection by the LEOSAR subsegment is greater in equatorial regions than at higher latitudes. Thus, as shown in Figure 5 and ***Figure 6***, LEOSAR and GEOSAR satellite transponders work in three ways:

1. UHF 406 MHz LEOSAR Local Mode – When the LEOSAR satellite receives 406 MHz distress signals, the onboard SAR processor (SARP) recovers the digital data from the beacon signal, measures the Doppler shift and time-tags the information. The result of this processing is formatted as digital data and transferred to the downlink for transmission to any LEOLUT in view.

2. UHF 406 MHz LEOSAR Global Mode – The 406 MHz SARP system provides near global coverage by storing data derived from the onboard processing of beacon signals in the LEOSAR spacecraft memory unit. The content of the memory is continuously broadcast on the satellite downlink. Each beacon can be located by a LEOLUT terminal, which tracks the satellite and provides global coverage with ground segment processing redundancy. The 406 MHz global mode also offers an additional advantage over the local mode with respect to alerting time when the beacon is in a LUT coverage area. As the beacon message is recorded in the satellite memory at the first satellite pass in the visibility of the beacon, the total processing time can be considerably reduced through the broadcast of the satellite beacon message to the first available LUT.

3. UHF 406 MHz GEOSAR Global Mode – Three GEO satellites equally spaced in longitude can provide continuous coverage of the globe between approximately 70 degrees north and 70 degrees south, excluding the polar regions. As the GEOSAR satellite remains fixed relative to the earth, there is no Doppler effect, so radio beacons need the GNSS receiver to provide a determination of the distress position. Location of distress is available only if beacon has a GNSS receiver chip and encodes the location in the beacon message. As shown in Figure 6, the detected distress signals are relayed by LEO and GEO satellites on 1544.5 MHz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or 4505.7 MHz (INSAT only) to the appropriate GEOLUT station, where the signals are processed to determine the location of the satellite beacons and/or a mobile in distress.[3,5,6,7,8]

MEOSAR Space Segment

The U.S., Russia and the European Commission/ESA have designed the Cospas-Sarsat subsegment that includes 406 MHz SAR repeater instruments on their respective MEO satellites together with GNSS networks of current U.S. GPS and Russian GLONASS, including forthcoming European Galileo. In such a way, an implementation plan for integrating MEOSAR components into the Cospas-Sarsat system (document C/S R.012) was developed in 2006 and can be downloaded from the Cospas-Sarsat website.

An innovative MEOLUT system will provide future service, such as: 1) Near global MEOSAR coverage with accurate independent location capability (no reliance on a navigation receiver), 2) Robust distress beacon-to-satellite communication links and a high level of satellite redundancy and availability and 3) Resilience to distress beacon-to-satellite link obstructions, i.e. satellite motion alleviates line-of-sight beacon-to-satellite blockages. Therefore, one of the main goals of the new MEOSAR system is to determine beacon location within 5 km, 95 percent of the time and within 10 minutes via 72 MEOSAR satellites positioned at MEO altitude.

Supporters of the Cospas-Sarsat system are preparing to evaluate a new capability of MEOSAR satellites, consisting of SAR transponders aboard navigation satellites of Europe, Russia and the U.S. (see ***Figure 7***). All distress signals sent from 406 MHz EPIRP, PLB and ELT are detected by the Distress Alerting Satellite System (DASS) GPS, GLONASS or Galileo GNSS transponders and resent to MEOLUT stations. From MEOLUT stations, position data goes to the MCC, RCC and RCC, which give instructions to SAR ships and helicopters. In that MEOSAR network, Galileo ground earth station (GES) can send MAM as a confirmation of receipt only via Galileo satellites. The MEOSAR satellites orbit the earth at altitudes ranging from 19,000 to 24,000 km (see ***Table 1***).[3,4,8,9,10]

USER SEGMENT

The Cospas-Sarsat user segment contains three radio beacons: EPIRB for ships, PLB for personal use or land vehicles (road and rails) and ELT for aeronautics applications. Future users have a list of all manufacturers of emergency satellite beacons presented in the Cospas-Sarsat system data brochure. Soon after purchasing a new or used emergency beacon it is necessary to register it with an authority indicating contact details and physical address.

1. Jotron Tron 60 S/GPS EPIRB – The Tron 60 S/GPS EPIRB (see ***Figure 8a***) is developed to meet the regulations and rules for use on large vessels and life rafts in the maritime service in SAR operations at sea. The author recommends that the aviation community use this type of EPIRB for installation onboard long-haul aircraft. It is buoyant and has water activated contacts that will start distress transmissions if deployed into water. The 60 S/GPS is currently available with two different brackets, one manual type and one float free version. The purpose of the Tron 60 S/GPS is to give a primary alarm to the SAR authorities. The EPIRB gives an

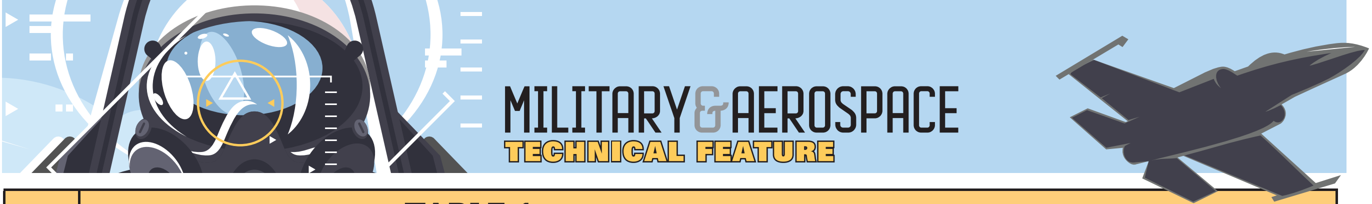

TABLE 1 MEOSAR SATELLITE CONSTELLATIONS

	MEOSAR Satellite Constellations	DASS/GPS	SAR/Galileo	SAR/GLONASS
Number of Satellites:	Total Operational I-orbit Spare With MEOSAR Payload	27 24 3 All GPS Block III Satellites	30 27 3 TBD	24 24 TBD(3) All GLONASS-K Satellites
	Altitude (km)	20,182	23,222	19,140
	Period (min)	718	845	676
Orbit Planes:	Number of Planes No. of Satellites per Plane(1) Plane Inclination (Degrees)	6 4 55°	3 9(2) 56°	3 8 64.8°

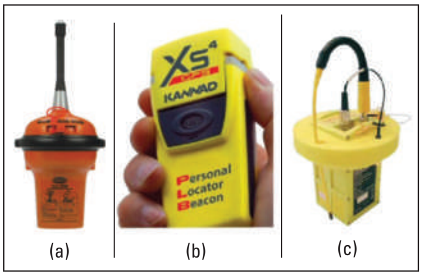

Fig. 8 Cospas-Sarsat EPIRB (a), PLB (b) and ELT (c) satellite beacons. *Source:* Joton and Orolia Kannad.

immediate alarm when activated, transmitting the ID of the ship in distress.

2. Orolia Kannad XS-4 PLB/With GPS – This beacon (see ***Figure 8b***) can be used for personal rescue primarily for pilots and aircraft crews, for the needs of various vehicles traveling in remote environments and for personal services. It has a three-stage operation: 1) lift the flip cover, 2) pull the anti-tamper cover to deploy the antenna and 3) push and hold the ON button to activate the PLB. Once activated it works for at least 24 hours. It is perfect to carry in addition to the onboard aircraft and other mobile radios.

3. Orolia Kannad 406 AS ELT – This survival beacon is intended to be removed from the aircraft and used to assist SAR teams in locating survivors of a crash at sea and on the ground (***Figure 8c***). Thanks to its small size and light weight, it fits easily inside a liferaft and it is supplied with a floating collar to enable the ELT to float upright if used in water (like the maritime EPIRB units). Its floating collar can be removed if the ELT is attached to a liferaft or any buoyant part. It is a standalone device equipped with an auxiliary antenna and activated manually by survivors or automatically by a "water switch sensor" when in contact with seawater. It is made of molded plastic with excellent mechanical resistance (ASA/PC, light yellow color). The housing is designed to be easily taken in one hand, and a tether is supplied to tie the ELT to a liferaft. [4,10,11,12,13]

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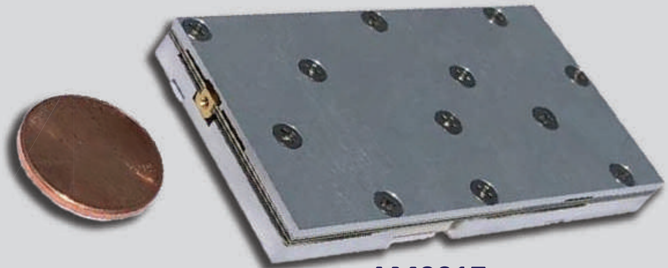

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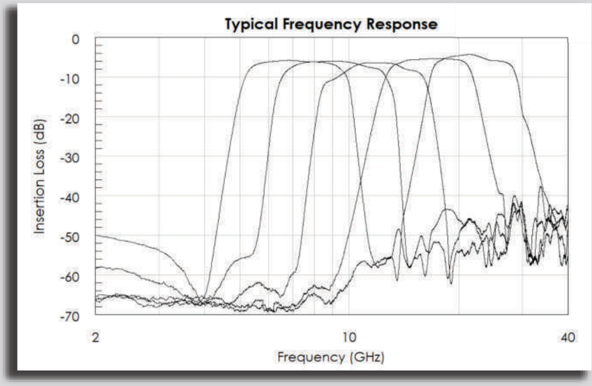

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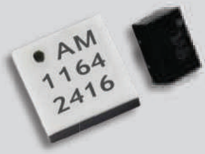

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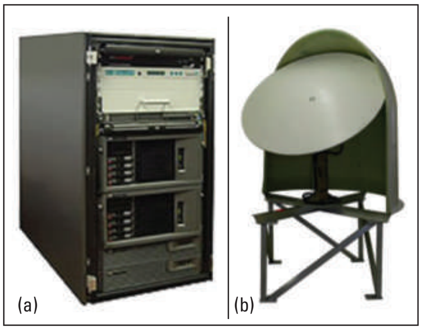
GROUND SEGMENT

The Cospas-Sarsat ground segment contains LUT ground stations, such as LEOLUT, GEOLUT and MEOLUT and MCC formations associated with RCC terminals and SAR infrastructures of ships, aircraft and helicopters for SAR missions.

1. Honeywell LEOLUT Receiver and Antenna – The LEOLUT unit single or dual LUT configuration (see ***Figure 9a***) combines LEO/GEO processing capability internalized satellite orbit data. This is a fully automated high performance LEOLUT that receives and processes distress signals from Cospas-Sarsat satellites and distributes location coordinates to the MCC. It maintains satellite orbit data internally, can be configured in a dual configuration and is the only LUT that can perform combined LEO and GEO data processing. Two methods are used to update the orbit: 1) tracking the downlink carrier to provide a Doppler signal using the LUT location as a reference and 2) using local calibration platforms operating at 406 MHz with accurately known locations. The LEOLUT antenna is a phased array that allows the LUT receiver to track satellites (see ***Figure 9b***). It is a lightweight, mast or roof-mounted antenna with digitally controlled motors to provide the entire range of motion required to track the Cospas-Sarsat satellites.



▲ Fig. 9 New generation LEOLUT (a) and antenna (b). *Source:* Honeywell.

2. Honeywell GEOLUT 600 GES – This model is a fully configurable ground terminal dedicated to meet SAR needs and exceeds distress data analysis requirements (see ***Figure 10a***). Combined with the LEOLUT 600, it can offer comprehensive SAR integration with unmatched response capabilities provided by the dual processing power of the LEO-GEO system. It provides rapid notification of 406 MHz distress beacon activations to SAR authorities. Using advanced signal processing technology and custom-designed software, the GEOLUT station offers 24-hour automatic monitoring of alerts over a large territory. In conjunction with LEOLUT data, the dual LEO-GEO system provides unrivaled processing capabilities to optimize beacon location accuracy and SAR response time. The LUT hardware comprises an HP processor, GPS clock and Comtech antenna (see ***Figure 10b***). The GEOLUT antenna is a fixed parabolic dish that allows the GEOLUT to receive distress alerts relayed through a single GEOSAR satellite.

3. Honeywell MEOLUT-600 Station – This MEOSAR station (see ***Figure 11a***) process 406 MHz distress alerts sent by the EPIRB, PLB and ELT beacons over next-generation GPS, GLONASS and Galileo MEO satellites and provides rapid notification to SAR authorities worldwide. It is part of an integrated Cospas-Sarsat MEOSAR solution developed by Honeywell Global Tracking, which bridges the existing LEO/LEO infrastructures and can con-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firm the location of an emergency alert within seconds. Its antenna (see ***Figure 11b***) is a 2.3 m (7.5 ft) mesh dish with radome that allows MEOLUT station to track MEOSAR satellite constellations.[3,4,11,14,15]

CONTROL CENTERS

The Cospas-Sarsat mission is to provide MCC and TCC terminals to coordinate between LUT stations and SAR forces.

MCCs

Cospas-Sarsat MCC terminals have been set up in most countries that operate at least one LUT (see ***Figure 12***). Their main MCC functions are to: 1) Collect, store and sort the data from all LUT stations and other MCCs and 2) Provide data exchange within the entire Cospas-Sarsat system and distribute alert and location data to the associated RCC or SPOC. Each MCC is responsible for distributing all alert data for distresses located in its service area (SA). An MCC SA includes aeronautical and maritime SAR regions in which the national authorities facilitate or provide SAR services and includes regions of other countries that have appropriate agreements for the provision of Cospas-Sarsat alert data.

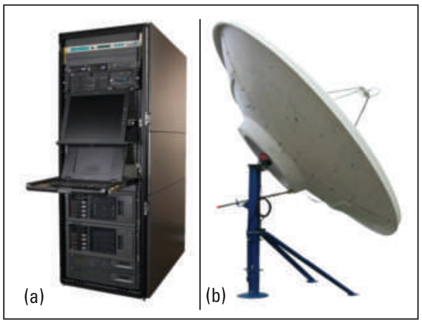

Fig. 10 New generation GEOLUT (a) and antenna (b). *Source:* Honeywell.

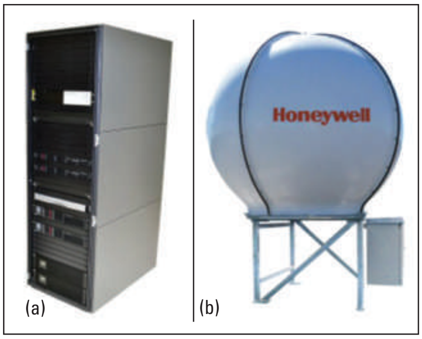

Fig. 11 MEOLUT (a) with antenna (b). Source: Honeywell.

Fig. 12 Cospas-Sarsat MCC terminal. *Source:* Cospas-Sarsat.

RCCs

The SARMaster solution provides comprehensive management of Cospas-Sarsat alerts. Alerts messages are displayed on the Geographic Information System while associated attribute information, such as frequency, time and search region of responsibility, is shown in a textual view. The TSi RCC workstation is internet enabled, putting the vast resources of the internet at the fingertips of the SAR mission planner. Several features of the RCC

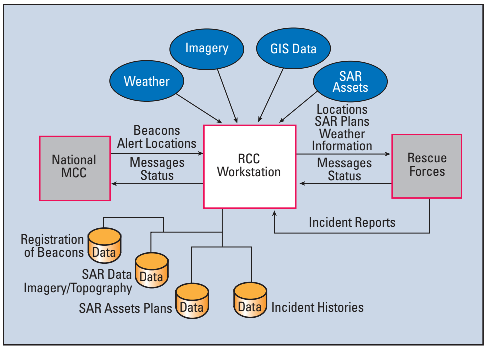

Fig. 13 Cospas-Sarsat RCC workstation block diagram. *Source:* Cospas-Sarsat.

workstation, including weather, satellite imagery and SAR information, are automatically updated from the internet. Data and information flowing into and out of the workstation are shown in ***Figure 13***. The Precision SAR Manager is a full-featured SAR management system that provides crucial, time-critical information to SAR personnel, resulting in safe and successful rescues. It ideally functions as an RCC workstation, communicating with MCC units or other national or international sites to receive distress calls and conduct a rescue. It also contains cutting-edge software for general SAR mission planning and analysis, resulting in a powerful SAR management system even without the benefit of Cospas-Sarsat.[3, 4,11,16]

CONCLUSION

The global SAR mission is a complex ecosystem of products, technologies and personnel with one universal goal—to save lives. The existing Cospas-Sarsat LEOSAR, MEOSAR and GEOSAR satellite network has saved five lives a day for the last 30 years. As the awareness and understanding of this ecosystem increases, from the moment of sending a distress alert to satellite connectivity, rescue coordination and solutions are increasing, so it will be possible to see new emerging applications, innovations and procedures that will save even more time and cost, all devoted to the mission of saving more lives.

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Professor Dimov Stojce Ilcev is a research leader and founder of the Space Science Centre for research and postgraduate studies at Durban University of Technology. He has three B.S. degrees in Radio, Nautical Science and Maritime Electronics and Communications. He received his M.S. and Ph.D. degrees in Mobile Satellite Communications and Navigation as well. Prof. Ilcev also holds the certificates for Radio operator 1st class (Morse), for GMDSS 1st class Radio Electronic Operator and Maintainer and for Master Mariner without Limitations. He is the author of several books on mobile radio and satellite CNS, DVB-RCS, satellite asset tracking and stratospheric platform systems for maritime, land (road and railways) and aeronautical applications.

Affordable, 43.5 GHz Real-Time Spectrum Analyzer Doubles As Vector Signal Analyzer

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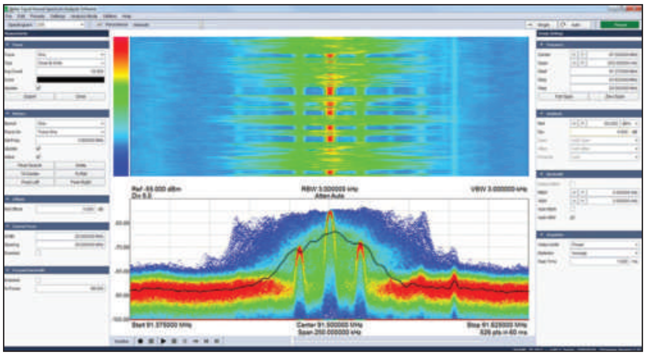
Signal Hound is launching its latest innovation in accurate and powerful spectrum analysis: the flagship SM435B 43.5 GHz spectrum analyzer expands frequency coverage to mmWave at an affordable and very competitive price point. It is available for pre-order and will be released mid-October 2021.

The SM435B is a high performance spectrum analyzer and monitoring receiver. Tuning from 100 kHz to 43.5 GHz, the analyzer has up to 160 MHz of instantaneous bandwidth (IBW), 110 dB dynamic range, ultra-low phase noise and 1 THz/sec sweep speed at 30 kHz resolution bandwidth (RBW) using Nuttall windowing. Currently the most affordable mmWave analyzer on the market, the SM435B offers performance rivaling the most expensive spectrum analyzers.



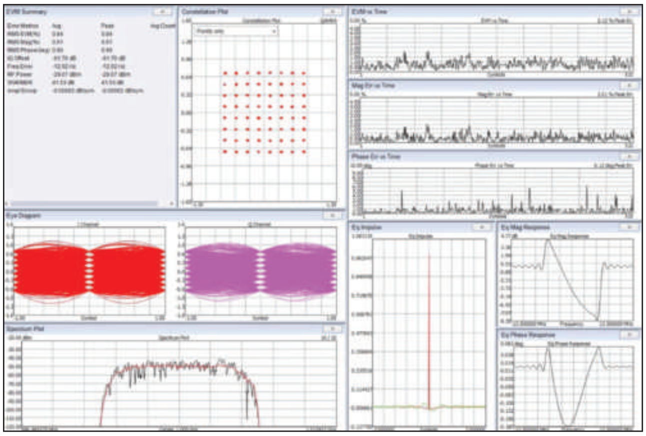
▲ Fig. 1 Real-time spectrum measurement using Spike with the SM435B.

The instrument's RBW range is from 0.1 Hz (≤ 200 kHz span) to 3 MHz (any span) with 40 MHz IBW or 30 kHz to 10 MHz with 160 MHz IBW. The SM435B offers 5 kHz to 40 MHz of selectable I/Q streaming bandwidth and can capture a 2 s I/Q block at 160 MHz IBW for external analysis on a PC. The I/Q streaming can be locked to GPS for precision time stamping.

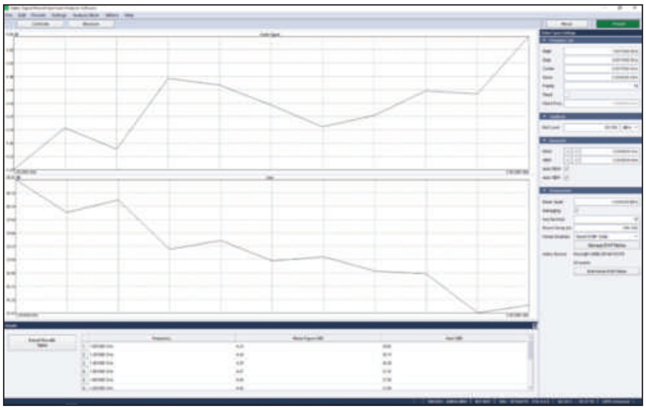
The accuracy of the SM435B's oven-controlled crystal oscillator is $\pm 5 \times 10^{-10}$ when locked to the GPS signal. Aging is specified at no greater than $\pm 5 \times 10^{-9}$ per day and thermal drift is within $\pm 1 \times 10^{-8}$ over -40°C to 65°C.

To ensure low VSWR over the mmWave frequency range, the instrument uses 2.4 mm connectors. Typical input VSWR is specified at 1.6:1.

Signal processing is distributed between a powerful Altera FPGA and an external PC with Intel Core i7 processor. Using its local API, the SM435B can interface to an automated moni-



▲ Fig. 2 With Spike, the SM435B performs digital modulation analysis with EVM measurements, doubling as a vector signal analyzer.



▲ Fig. 3 With Spike, the SM435B offers a noise figure analysis mode, providing noise figure and gain measurements and data export.

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toring system or automated test equipment, providing the capability for users to insert their own DSP algorithms into a calibrated stream of I/Q data.

Spike™ Software Adds Capabilities

Spike, Signal Hound's proprietary and complementary spectrum analyzer software, is included with the SM435B. Compatible with the entire line of Signal Hound spectrum analyzers and tracking generators, the software provides full device control, a configurable spectrogram display, user interface and a variety of analysis modes, adding powerful RF analysis capabilities. Spike adds several capabilities that enhance the spectrum analyzer's measurements:

Real-Time Spectrum Analysis — In today's wireless environment, serious measurements require real-time capabilities. With many signals—complex modulated communications, interference, pulsed tactical signals—the signal energy is sporadic, non-recurring or even random. With traditional spectrum analysis, these signals are nearly impossible to catch in an analyzer window or trigger on. Spike enables real-time measurements (see ***Figure 1***).

Digital Modulation Analysis — In addition to the spectrum display, Spike's digital modulation analysis capabilities turn the spectrum analyzer into a vector signal analyzer with the capability to perform EVM measurements and view the constellations of several PSK and QAM modulations (see ***Figure 2***).

Noise Analysis — The noise figure mode measures noise figure and gain (see ***Figure 3***). The noise figure is computed using the Y factor technique from several measurements taken by the SM435B. The data can be exported in a CSV format for analysis.

Phase Noise — Spike's phase noise measurement application enables single sideband phase noise to be measured. The simple, industry standard phase noise measurement is straightforward and makes the SM435B a cost-effective phase noise test system.

Summary

Signal Hound has a tradition of providing value and performance in RF signal analysis and generation. That tradition continues with this latest model in the SM line of spectrum analyzers. Offering features to help measurement workflow on the lab bench, the production line or in the field, the SM435B extends advanced spectrum analysis to 43.5 GHz. The analyzer provides a good entry point for affordable access to mmWave spectrum analysis, whether using Signal Hound's application programming interface, third-party or in-house custom software. This high performance, affordable spectrum analyzer supports test and analysis needs, able to monitor new waveform standards, including 5G.

As Signal Hound prepares the SM435B for production and delivery, the company wants valued customers and Signal Hound enthusiasts to have the opportunity to pre-order and plan for procurement in early Q4 of this year. Signal Hound's customer service team can assist with pre-production purchase orders.

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Reconfigurable Filter for Military Radio Using MEMS Switches

A reconfigurable filter bank using Menlo Micro's "Ideal Switch" technology offers high-power handling, high IP3 and little variation over temperature. Developed for land, air and seaborne military radios, the filter covers the primary military VHF and UHF bands from 225 to 512 MHz and can be scaled to operate in the HF bands.

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MEMS switches have several advantages over solid-state technologies: lower loss, higher input power handling and better RF linearity. MEMS designs have very low "on" resistance, which provides the lowest possible insertion loss, and the low "off" capacitance reduces signal leakage in the "off" state. These lower parasitics enable high-Q tunable resonators with little degradation in RF performance compared to a fixed resonator design.

MEMS switches have ultra-low mass, which withstands extreme shock and vibration without any detectable performance degradation from the switches. Filters using the MEMS switch operate over wide temperature ranges with thermal dissipation and RF variation over temperature much lower than comparable solid-state designs. These factors contribute to significant size, weight, power and cost advantages over traditional tunable or switched filter banks for military radios. The lifetime of Menlo Micro's MEMS switch technology is more than 3 billion on/off switching operations, which supports the long lifetime requirements of military radios.

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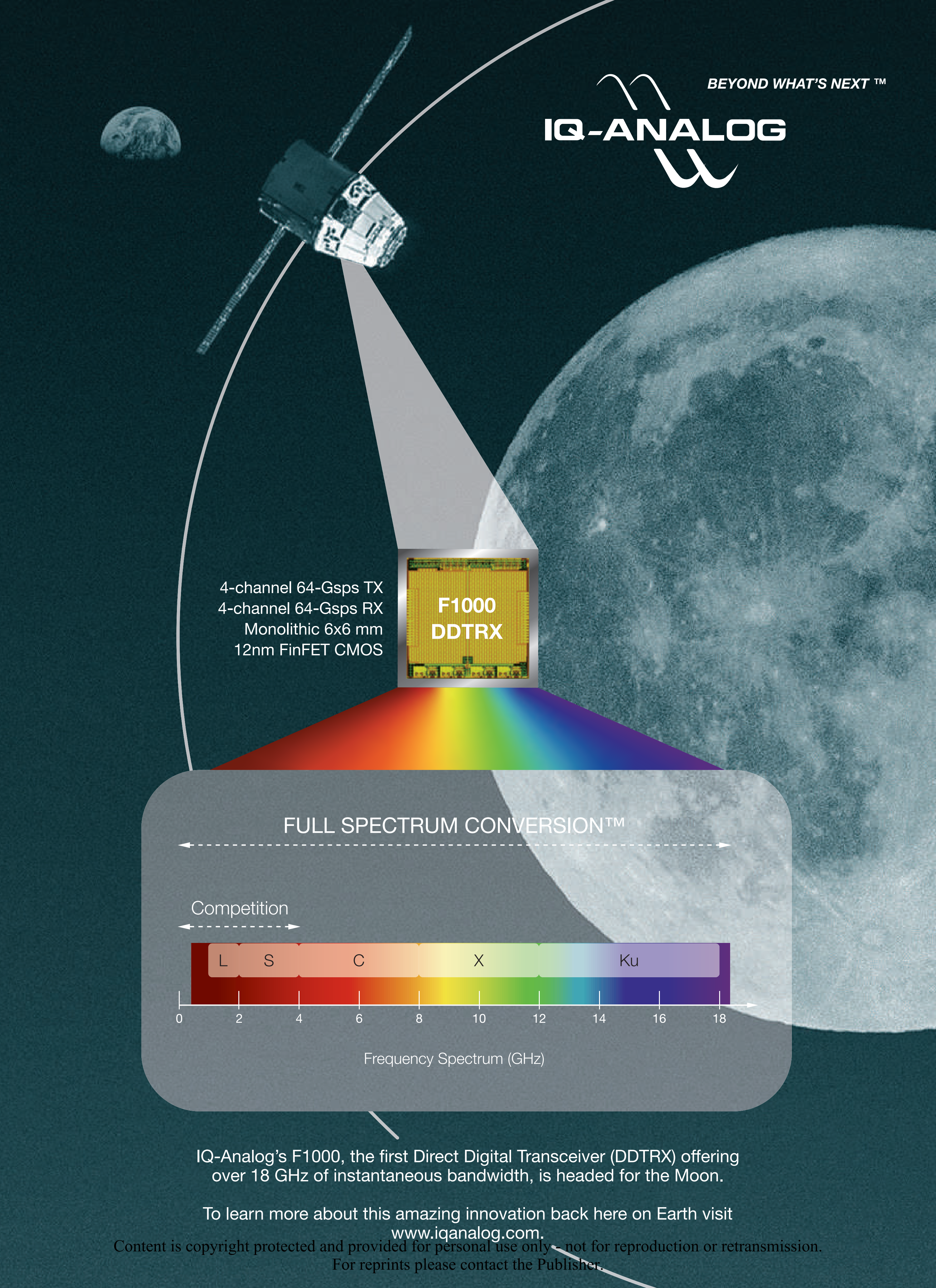
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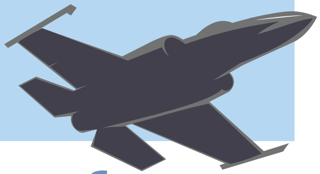

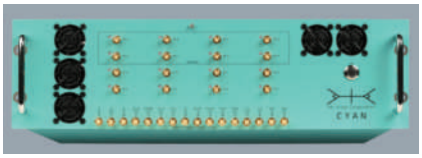

SDR with Storage for Spectrum Monitoring, Recording and Playback

With large channel bandwidths and extensive processing power, software-defined radios (SDRs) are well-suited for spectrum monitoring. However, significant digital data is generated from the slices of the spectrum that are captured and stored for analysis. The Cyan platform with storage is a high performance SDR from Per Vices that can scan from near DC to 18 GHz, with the capability to extend the range to 40 GHz. Cyan can be configured with up to 16 independent radio channels, each with 1 GHz bandwidth. The bandwidth of each channel is adjustable to provide flexibility from wide bandwidth scanning to narrow spectrum monitoring.

A Stratix 10 FPGA enables Cyan to gather and analyze a large amount of data. The FPGA has the resources to implement digital signal processing algorithm, and Per Vices can develop or integrate specific IP or license the source code. To handle the data transfer to the host, Cyan supports a 4 x 40 Gbps connection over qSFP+ ports in a VITA49 data format.

Supporting Cyan, Per Vices' data storage solution has the capacity to handle the 160 Gbps data stream without any losses. Various storage capacities are available, up to 100 TB, and additional computational resources are available for post processing the received data. Cyan and its data storage can be accessed through an Ethernet connection, for remote control and processing. The flexibility and ability to update the software make this SDR an investment that will adapt to future requirements.

Per Vices can customize any of their products to meet specific customer needs: adding channels, extending the operating frequency, increasing the bandwidth and digital backhaul or enhancing other RF specifications.

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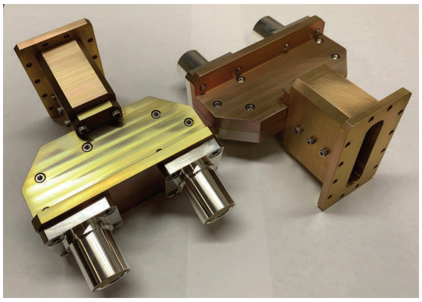
www.pervices.com



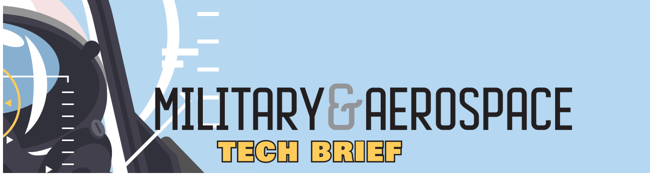
S-, C- and X-Band Combining Networks for High Power Amplifiers

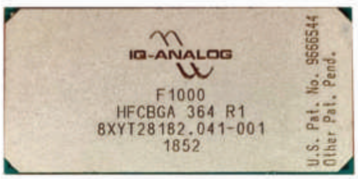
With the need to increase the output power from solid-state power amplifiers (PAs), combiner network efficiency is a critical parameter. Traditional PA power dividers and combiners use either a coaxial approach or waveguide spatially matched structures, with the design approach depending on the operating frequency and power requirements. For higher power and higher frequency, waveguide structures are often employed; occasionally, tuned cavity combiners are used. At low frequencies, designers are primarily limited to a microstrip or balanced stripline architecture. As the power levels increase, waveguide combiners are necessary to adequately dissipate the heat; however, this results in a larger component footprint.

M Wave Design Corporation has more than 35 years of passive design experience developing efficient combining networks for S-, C- and X-Band. As one example of M Wave Design's capabilities, the 284CA1213 is a 2:1 S-Band combiner using proprietary, high-power QD connectors with a WR284 half-height waveguide output. The combiner is part of an integrated 16:1 network developed for an industry leading solid-state PA supplier.

M Wave Design uses some of the most innovative channel summing techniques in its power combiner designs. In addition to power divider/combiners, its expertise includes low- and high-power circulators. Operating in a new 6,600 square foot manufacturing facility in Simi Valley, California, M Wave is vertically integrated with a CAD to manufacturing workflow to reduce lead times. Internal environmental test capabilities can perform vacuum and leak testing, temperature testing including thermal shock and cycling and cryogenic testing to 70K. M Wave is ISO-9001:2008 certified and ITAR registered.

M Wave Design Corporation
Simi Valley, Calif.
www.mwavedesign.com





Antenna Processor Enables All-Digital Radar, EW and Communications

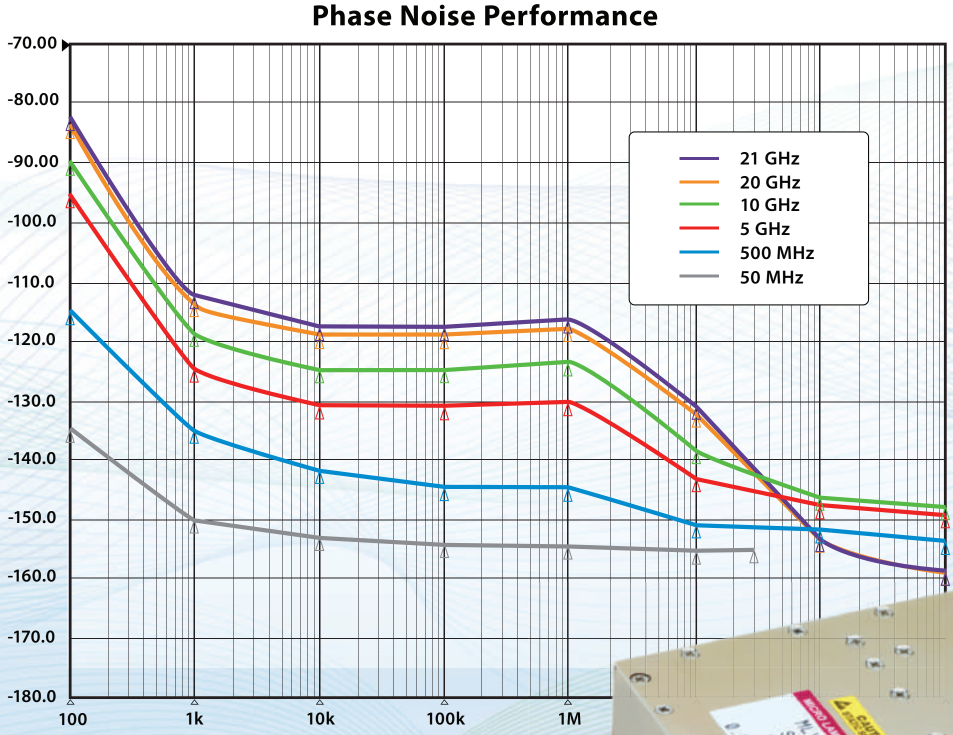
To enable the next generation of radar, electronic warfare (EW) and communications systems to move from analog to all-digital antenna processing, IQ-Analog has developed the F1000 antenna processor unit (APU). The F1000 is the flagship of a complete APU product line to dynamically reconfigure multi-function antenna arrays with cognitive software control. These next-generation, multi-function active antennas can provide concurrent spatial beams with converged radar, communications and EW functions.

The F1000 offers size, weight and power benefits through monolithic integration of high speed data conversion and digital signal processing in a FinFET IC. The APU offers Full-Spectrum Conversion® with over 30 GHz instantaneous bandwidth. This is accomplished with a new data conversion architecture known as traveling pulse wave quantization that delivers more than 10x the data capacity of conventional architectures. Digital fast frequency hopping with dual-band processing in each converter channel and dual RISC-V control processors provide more than 180 TeraOps of embedded digital processing. The F1000 is manufactured domestically on a 12 nm FinFET CMOS process and can be provided as bare die or in a 10 x 20 mm ball grid array package. Available for sampling, the F1000 is supported with a hardware evaluation platform and software development kit.

IQ-Analog is an emerging semiconductor product company developing a family of APUs for both defense and commercial markets. IQ-Analog has a patent-protected integration advantage in wideband transceiver technology with the goal of serving a large share of emerging high volume commercial markets. The APUs are designed to help accelerate the rollout of commercial 5G networks, automotive radar, automotive LiDAR and connected car systems. The capabilities of the F1000 and a new common platform of APU components are enabling a technology refresh of legacy analog systems.

IQ-Analog,
San Diego, Calif.
www.iqanalog.com

Lowest Noise in the Industry



US patents #9,793,904 B1, #9,734,099 B1

Wide Band, Fast Tune Frequency Synthesizers

Industry Leading Performance!

The LUXYN™ MLVS-Series Frequency Synthesizers from Micro Lambda Wireless is one of the fastest and quietest synthesizers on the market. Standard frequency models are available covering 500 MHz to 20 GHz and 500 MHz to 10 GHz with options to cover down to 50 MHz and up to 21 GHz in a single unit.

With the lowest noise in the industry, (phase noise at 5 GHz is -130 dBc/Hz @ 10 kHz offset and at 10 GHz is -125 dBc/Hz @ 10 kHz offset), these synthesizers are designed for low noise & fast tune applications such as Receiving Systems, Frequency Converters and Test & Measurement Equipment.

For more information contact Micro Lambda Wireless.

www.microlambdawireless.com

Micro Lambda is a ISO 9001:2015 Registered Company

MICRO LAMBDA WIRELESS, INC.

"Look to the leader in YIG-Technology"

46515 Landing Parkway, Fremont CA 94538 • (510) 770-9221 • sales@microlambdawireless.com

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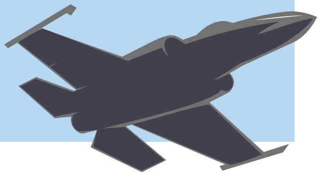
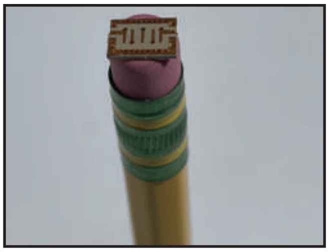
COMPANY SHOWCASE





3H Filters

3H printed filters field proven for military, space and commercial applications, frequency range: 5.0 GHz to 47 GHz, type: BPF, LPF, HPF, BRF and multiplexer options, bandwidths: 1.0 to 60 percent Chebyshev Response, low profile packages start at a < 0.065. Available with Connectors and SMT, Mil-Std-202 Conditions.

3H Communication Systems
www.3hcommunicationsystems.com

ADAR3000: 17 to 22 GHz Frequency Range Beamforming IC

VENDORVIEW

Analog Devices has developed the ADAR3000 and ADR3001 beamformer integrated circuits (BFICs). These highly integrated, low-power BFICs are the first commercially available four-beam/16-channel that support the K/Ka-Band satcom bands–both terminal and satellite applications. These BFICs have internal memory to support beam hopping and scanning requirements.

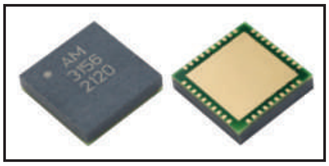
Analog Devices
www.analog.com/en/products/adar3000.html

Silicon ICs for Aerospace & Defense Electronically Steered Antennas

VENDORVIEW

Anokiwave has been providing mmWave technology for A&D applications for over 21 years and is now enabling new capabilities in satcom, radar, electronic warfare (EW), COMMs, NextG and space by leveraging the advances in mmWave Si commercial technologies. The company's solutions offer small SWaP-C, flexibility to customize for specific needs, and a phased IC development approach to meet budgetary constraints. Contact Anokiwave now to discuss your specific A&D needs at www.anokiwave.com/A&D.

Anokiwave
www.anokiwave.com/a_d/index.html?utm_source=mwj&utm_medium=adsupp&utm_campaign=2021_sept_ad_supp

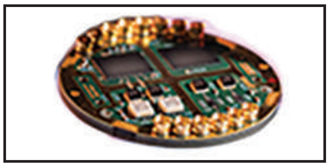


Low SWaP Component Solutions from Atlanta Micro

VENDORVIEW

Atlanta Micro has developed the AM3156, a fully integrated miniature digitally tunable bandpass filter bank covering 0.4 to 8 GHz. The device exhibits three filter bands each with 256 discrete tune states and a low-loss filter bypass path contained in a 10 mm QFN package. AM3156 is an excellent front-end for a receiver providing both low insertion loss and valuable flexibility for tuning center frequency and bandwidth. Its small size, weight and power consumption are ideal for demanding applications requiring low SWaP components.

Atlanta Micro
www.atlantamicro.com/filters



Microwave Array Technology for Reconfigurable Integrated Circuits (MATRICs®)

BAE's high bandwidth MATRICs® microwave transceiver platform unites programmable military grade chips and multiple RF technologies into one system that can be reconfigured rapidly, even in harsh environments. Learn more today by contacting BAE's FAST Labs™ representative at es.flcommunications@baesystems.com.

BAE Systems
www.baesystems.com/matrics

Rack Mount Broadband GaN High-Power Amplifiers

VENDORVIEW

Cernex's line of GaN rack mount amplifiers are high-power, efficient and can be customized to your project's needs. The model CBPG30404040R-01 has a large band from 30 to 40 GHz, a high 40 dB gain and an output of 40 dBm. It is packaged in a 4U rack mount with cooling apparatus included and runs on standard AC power so it will always be ready to strengthen your RF signal whenever you need.

Cernex, Inc.
https://cernex.com/

Comtech PST Develops Digital Attenuator

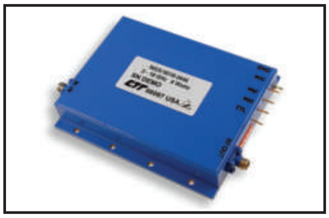
Comtech PST developed a digital attenuator that has 60 dB of attenuation control from 400 to 500 MHz. The digital attenuator is TTL control to select attenuation ranges, with four-bit control. The digital attenuator has excellent accuracy, achieving ±0.25 dB from 0 to 36 dB range, and ±0.50 over 36 dB range. The insertion loss is less than 1.5 dB and the VSWR is less than 1.5:1. For additional information or to download the datasheet visit comtechpst.com or email sales@comtechpst.com.

Comtech PST
comtechpst.com

Communications & Power Industries: Your Source for High-Power Microwave Components

CPI is the industry's largest manufacturer of receiver protectors. CPI designs and manufactures a broad range of RF and microwave products for radar, communications, EW, medical and scientific applications. They also manufacture a broad range of pressure windows and pressure bypass windows. Their products are found in numerous radar systems operated by the U.S. military and militaries around the world. Contact CPI at www.CPII.com or ElectronDevices@CPII.com for high-power microwave components.

CPI International Inc.
www.cpii.com



2 to 18 GHz, 8 W GaN Power Amplifier

CTT's solid-state GaN-based power amplifier, Model AGX/0218-3946, covers 2 to 18 GHz with 8 W (+39 dBm) of CW power output. The compact size of 4.25 (L) x 3.25 (W) x 0.88 in. (H) offers RF/microwave designers an excellent choice for SWaP-C solutions in many S- through Ku-Band applications, including EW, radar and satcom. CTT can provide many replacement amplifier products from companies including Avantek, Amplica, Inc., Celeritek and Watkins-Johnson.

CTT Inc.
www.cttinc.com

L-Band 30 kW Solid-State Transmitter Building Block

Daico introduces an EIA 19" Common Platform Transmitter Building Block, Part Number CTX09664, that delivers 30 kW 2 mSec pulse power at L-Band with unprecedented availability, reliability, maintainability and affordability. Highlighted features include automatic failover, graceful power degradation and true "hot-Swap" capability. The ultra-reliable CTX09664 Building Block outperforms Klystron and TWT technologies. This flexible and scalable transmitter architecture can be implemented to achieve hundreds of kW power at up to C-Band in an air or liquid cooled environment.

Daico Industries, Inc.
www.daico.com

I- and Ka-Band Integrated Stabilized RF Sources

Integrated stabilized RF sources (ISRFS) designed for radars, radar simulation, ECM, EW threat simulation, test and measurement. dB Control designs and manufactures ISRFS units: dB-9003 (8 to 12 GHz and 30 to 36 GHz) and dB-9005 (30 to 36 GHz) which are customizable. Featuring four types of modulation (AM, FM, Pm and Pulse), high accuracy and wide temperature operating ranges. They can be controlled and set up with a digital port.

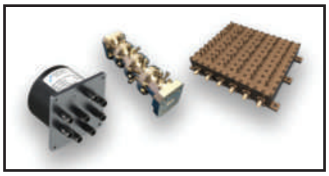
dB Control
www.dBControl.com

Expanding the Boundaries of Performance and Dependability

VENDORVIEW

ERZIA is a leader in the design and manufacture of amplifiers and microwave assemblies for extreme environments where high reliability, low noise, high efficiency, compactness and ruggedness are mandatory. ERZIA's mission is to deliver the solutions that take you further.

ERZIA
www.erzia.com



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. Exceed provides various types of designs, each with its own unique values and are designed and made in U.S. Many of Exceed's designs offer extremely high-q factor, allowing very low insertion loss and high-power handling.

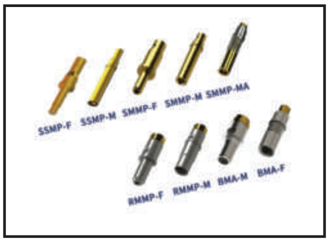
Exceed Microwave
www.exceedmicrowave.com

Exodus Advanced Communications Delivers Products 10 kHz to 51 GHz

VENDORVIEW

Extremely ruggedized product lines utilizing LDMOS, GaN (HEMT) and GaAs devices to produce amplifiers with technology advancements. Low, medium and high-power amplifiers with chip and wire technology, Exodus provides the widest range of stand-alone modules and integrated amplifier systems satisfying demanding applications. Decades of RF and microwave experience providing LNAs and SSPAs with unprecedented reliability and performance no matter how harsh the operating environment for military jamming, radar, communications and commercial EMI/EMC applications.

Exodus Advanced Communications
www.exoduscomm.com



1.1 to 1.7 GHz High-Power Drop-In 90-Degree Hybrid

MIcable QT11001700 is a 1.1 to 1.7 GHz high-power drop-in 90-degree hybrid that can handle 400 W CW power. It can be directly welded in the circuit, which takes up less space, and has excellent stability and heat dissipation ability.

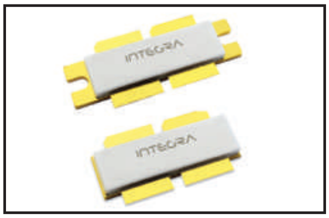
Fujian MIcable Electronic Technology Group Co., Ltd.
www.micable.cn

Ultra-Flexible Phase Stable Cables

VENDORVIEW

HASCO, Inc., a global supplier of just-in-time RF and microwave components, is expanding their line of high performance cable assemblies to include their new Ultra-Flexible Phase Stable Cables. These competitively priced cable assemblies provide the perfect solution for mmWave lab testing, featuring an ultra-flexible durable design, a phase stability of 3 degrees and amplitude stability of 0.3 dB at 26.5 GHz while under flexure, making this cable series ideal for high volume production test applications.

HASCO, Inc.
www.hasco-inc.com



100 V RF GaN: IGN1011S3000 and IGN1011S3000S

IGN1011S3000 and IGN1011S3000S are the industry's first RF GaN/SiC products operating at 100 V. These high-power RF GaN/SiC transistors enable next generation IFF/SSR avionics systems while dramatically reducing size and weight. They operate at both 1030 and 1090 MHz. Under 32 ms, 4 percent duty cycle pulse conditions, they supply a minimum of 3000 W of peak output power and > 19 dB of gain at 75 percent efficiency. They are packaged in a metal-based package with an epoxy-sealed ceramic lid for optimal thermal efficiency.

Integra Technologies Inc.
www.integratech.com

Directional Coupler Covers 0.5 to 8.0 GHz

VENDOR**VIEW**

KRYTAR couplers offer solutions for many applications including EW, commercial wireless, satcom, radar, signal monitoring and measurement, antenna beam forming and EMC testing environments. Model 158030 offers superior performance ratings including nominal coupling of 30 dB, ±0.8 dB, frequency sensitivity of ±0.6 dB, insertion loss less than 0.80 dB, directivity of greater than 16 dB, VSWR is 1.35 and SMA Female connectors. The package measures just 5.25 (L) x 0.53 (W) x 0.72 in. (H) and weighs only 3.8 ounces.

KRYTAR
www.krytar.com

RF Power Sensors

VENDOR**VIEW**

LadyBug Technologies' LB5944A, 44 GHz USB power sensor offers several features specifically designed for defense users. These include Option MIL, which prevents the storage of information inside the sensor; and Option SEC, a secure erase feature that allows sensitive users to erase any settings, offsets or data that have been stored within the sensor prior to the sensor leaving the secure environment. Additionally, the sensor utilizes LadyBug's patented active thermal stabilization which eliminates drift associated with accurate low-power measurements.

LadyBug Technologies
www.LadyBug-Tech.com

MCV Microwave High Performance Exact Shape Ceramic Filters

VENDOR**VIEW**

MCV Microwave, a leader in high-quality dielectric resonator, substrate and filter, is offering high performance exact shape ceramic filters to space, aerospace defense and military industries. These bandpass filters exhibit low passband insertion loss, sharp roll off, maintain ultimate rejection, exact shape with matched delay. For example, A 2,300 MHz filter has ~0.5 dB insertion loss over 25 percent bandwidth and 40 dB near band rejection up to 5 to 6 GHz Wi-Fi band in 2" x 0.6" x 0.4" package, as shown.

MCV Microwave
www.mcv-microwave.com

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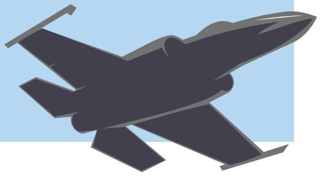
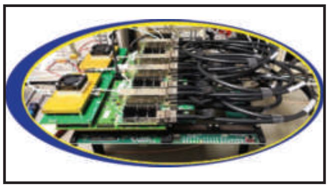
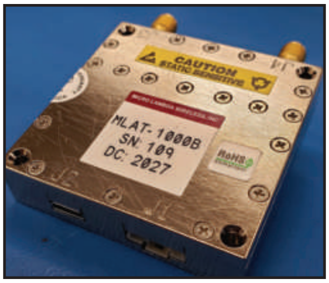




Ultra-Fast ADCs/DACs Power Micram USPA Rapid Prototyping

Micram USPA is a new modular rapid prototyping platform, integrating 72 GS/s Micram VEGA ADC and DAC signal converters with a broad range of Xilinx and Intel FPGAs. USPA is a flexible, programmable real-time environment for extremely high speed signal processing, with powerful capabilities in telecommunications research, ultra-fast data generation and acquisition and in ASIC/SoC design applications. USPA delivers both leading edge performance and remarkable cost effectiveness compared with custom platforms, cutting development time and cost.

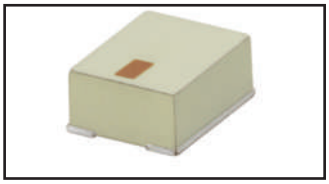
Micram
www.micram.com



New Programmable Attenuators Covering 10 MHz to 21 GHz

New programmable attenuators: standard frequency models are available covering 10 MHz to 21 GHz and provide either 31.5 or 63 dB of attenuation over the full frequency range. Units are fully programmable by the user. Model MLAT-1000A 10 MHz to 21 GHz/31.5 dB attenuation, Model MLAT-1000B 10 MHz to 21 GHz/63 dB attenuation. Applications include wideband receivers, automated test systems, telecom, satcom, UAVs and drones and a variety of military and commercial test applications.

Micro Lambda Wireless
www.microlambdawireless.com



Substrate Integrated Waveguide (SIW) LTCC Bandpass Filter

VENDORVIEW

Mini-Circuits' BFCV-2852+ is the industry's first SIW filter on LTCC substrate. This model allows for precise filtering over a narrow passband from 28 to 28.8 GHz. BFCV-2852+ provides insertion loss as low as 2.3 dB and stopband rejection up to 35 dB combined with all the benefits of LTCC technology including a tiny size (3.2 x 2.5 mm) outstanding reliability and repeatable performance for volume production.

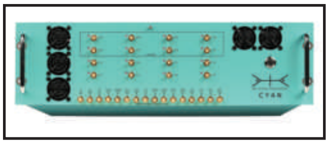
Mini-Circuits
www.minicircuits.com/WebStore/dashboard.html?model=BFCV-2852%2B

Norden Millimeter's 18 to 40 GHz Down-Converter

VENDORVIEW

The NDC18401O217N14 is an 18 to 40 GHz downconverter, part of Norden Millimeter's expanding line of catalog and custom frequency converters. This product is available with a 0.5 to 18 GHz bypass channel and hermetic case. Custom designs incorporate temperature compensation, variable gain and meet military environmental requirements. Norden can also provide RF and microwave assemblies which include frequency conversion, switch matrices, amplifiers, LNAs and filters.

Norden Millimeter
www.NordenGroup.com

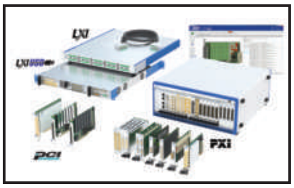


Cyan High Bandwidth

Cyan High Bandwidth offers the same excellent radio performance as Cyan with more bandwidth, offering 3 GHz per radio chain and up to eight radio chains per system. This results in the ability to capture 18 GHz of bandwidth and is met by an equally impressive digital interface that enables data to be sent over 4 x 100 Gbps Ethernet connections. Together with the flexible channel count, highest RF bandwidth and highest digital backhaul in the industry, Cyan High Bandwidth offers unmatched performance.

Per Vices

www.pervices.com/documentation-cyan-high-bandwidth



PXI, LXI and USB Switching, Simulation and Software for A&D

Pickering Test Solutions understands that aerospace/defense engineers have unique testing needs. The company's products, ranging from general purpose switching, fault insertion for HIL simulation to RF/microwave switching and sensor and VDT simulation, help simplify and expedite your test systems' development and deployment.

Pickering Test Solutions

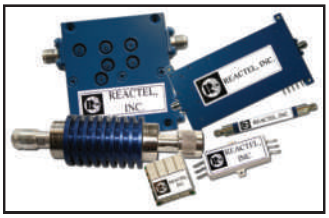
https://hubs.ly/H0Tb_Ld0

Pixus USA Opens and Joins SOSA™ Consortium

Pixus Technologies launched Pixus Technologies USA Corporation with an office opening near Buffalo, N.Y. The company has also joined the Sensor Open Standard Architecture (SOSA) Consortium. Canadian-based Pixus Technologies Inc has been providing ruggedized and commercial OpenVPX and other COTS backplane/enclosure solutions for over ten years. The company is ITAR/Controlled Goods Program (CGP) registered with a focus on the North American defense market. The Pixus USA location helps facilitate a faster process for setting up Pixus in export control compliance.

Pixus Technologies

https://pixustechnologies.com/assets/Press-Releases/Pixus-PR-Pixus-USA-opens.pdf



Filters, Multiplexers and Multifunction Assemblies

VENDORVIEW

Reactel manufactures a line of filters, multiplexers and multifunction assemblies covering up to 50 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—Reactel's talented engineers can design a unit specifically for your application. Visit Reactel online at www.reactel.com.

Reactel

www.reactel.com

Two New Products Coming Soon from Signal Hound!

Signal Hound continues to deliver value to the market with the introduction of its new SM435B 43.5 GHz Spectrum Analyzer (October 2021) and BB60D 6 GHz Real-Time RF Analyzer (Q1 2022). The SM435B features ultra-fast analysis from 100 kHz to 43.5 GHz, 110 dB of dynamic range, 1 THz/sec sweep speeds and ultra-low phase noise. The BB60D offers up to 27 MHz of selectable IF bandwidth, 10 dB more dynamic range than the BB60C and 24 GHz/sec sweep speeds.

Signal Hound

https://bit.ly/3iUeLDa

SPINNER Rotary Joints Fly to Mars

VENDORVIEW

The Chinese Tianwen-1 Mars mission carried special space-appropriate single- and dual-channel X-Band rotary joints from SPINNER on board. Following its launch on July 23, 2020, it became the first Chinese spacecraft to go into orbit around the red planet on February 10, 2021. Rotary joints from SPINNER are making a crucial contribution to driving technological advances and enabling precise communication in outer space. Outer space is probably one of the harshest environments in which SPINNER's products are used, they must meet the strictest imaginable requirements in terms of reliability, precision and quality.

SPINNER

www.spinner-group.com

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AOC INTERNATIONAL SYMPOSIUM & CONVENTION

NOV. 30-DEC. 2, 2021

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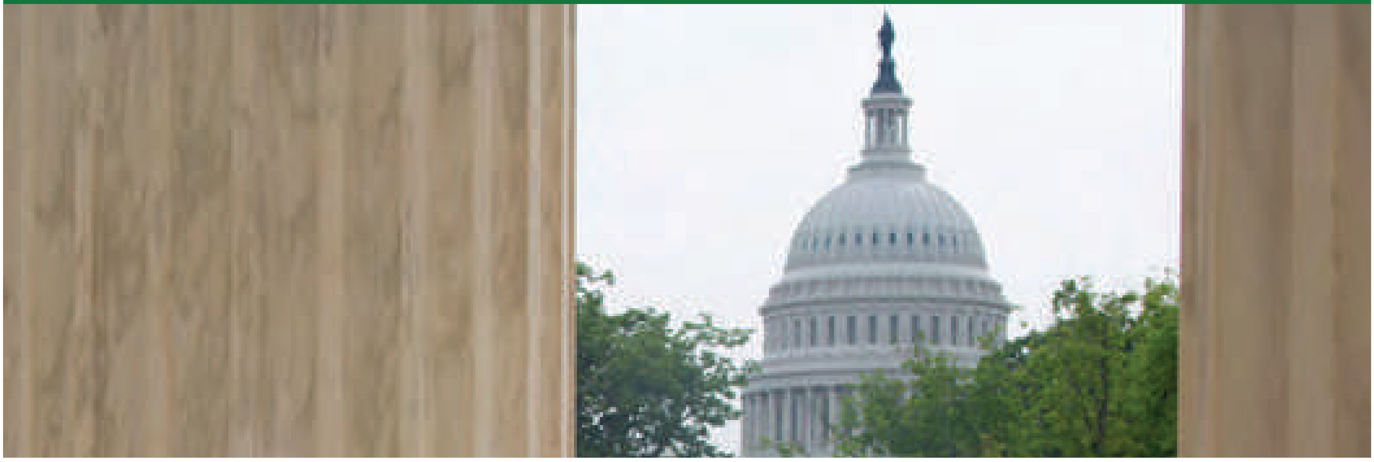

WHO SHOULD ATTEND

AOC 2021, the Association of Old Crow's Annual Symposium & Convention, brings together the *full spectrum of people* working in electromagnetic spectrum operations.

ACTIVE DUTY TO VETERAN

No matter what your mission, you need an advantage in the spectrum. A better understanding of the invaluable role of spectrum in military operations is imperative for success.

JUNIOR ENGINEER TO PRINCIPAL ENGINEER

You are the technology makers, the rapidly evolving designers. Through research and development, you are solving the problems and providing the solutions to the war fighters.

CASUAL TO PRO

The spectrum is part of your world and touches everything you do. You need to join our mission in order to gain the knowledge you need to drive decisions in your organization.

SUPPORT OUR MISSION • INFLUENCE OUR MISSION • LEARN OUR MISSION