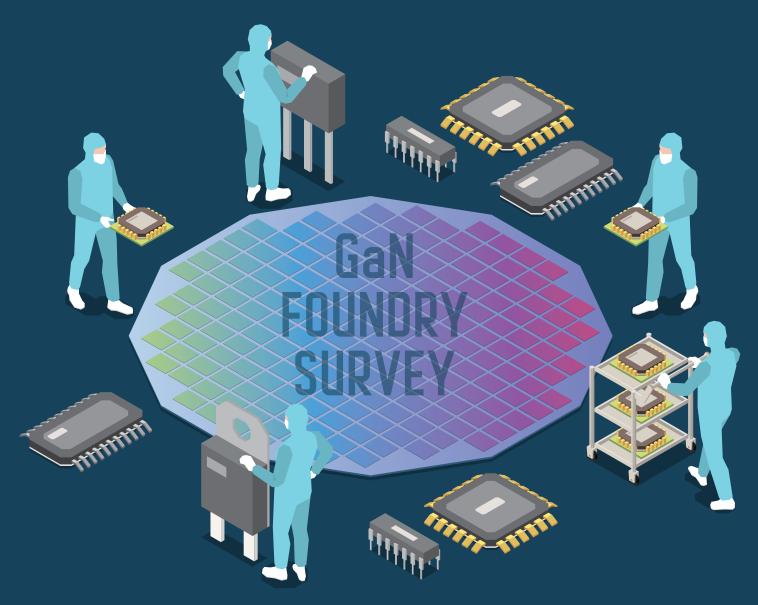
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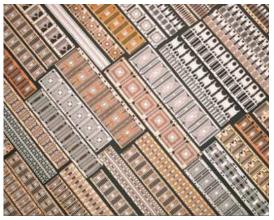
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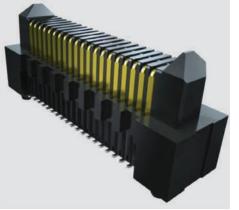


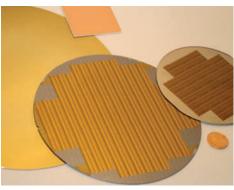
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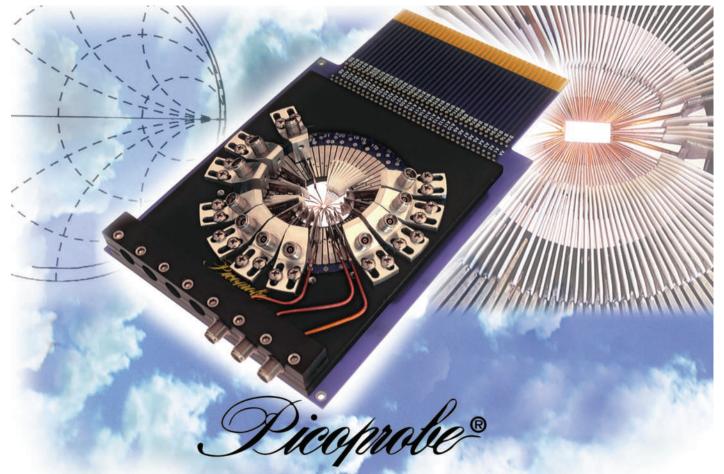
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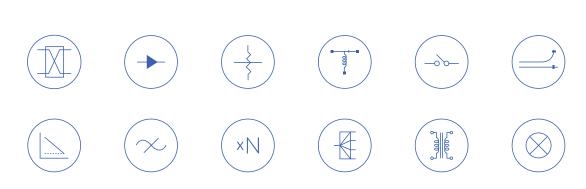


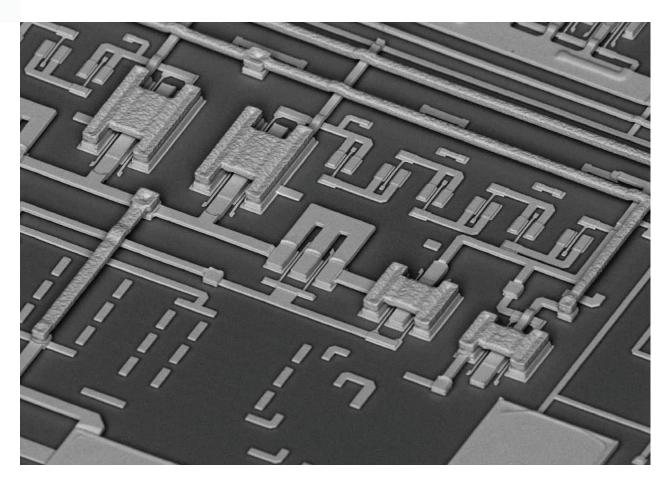








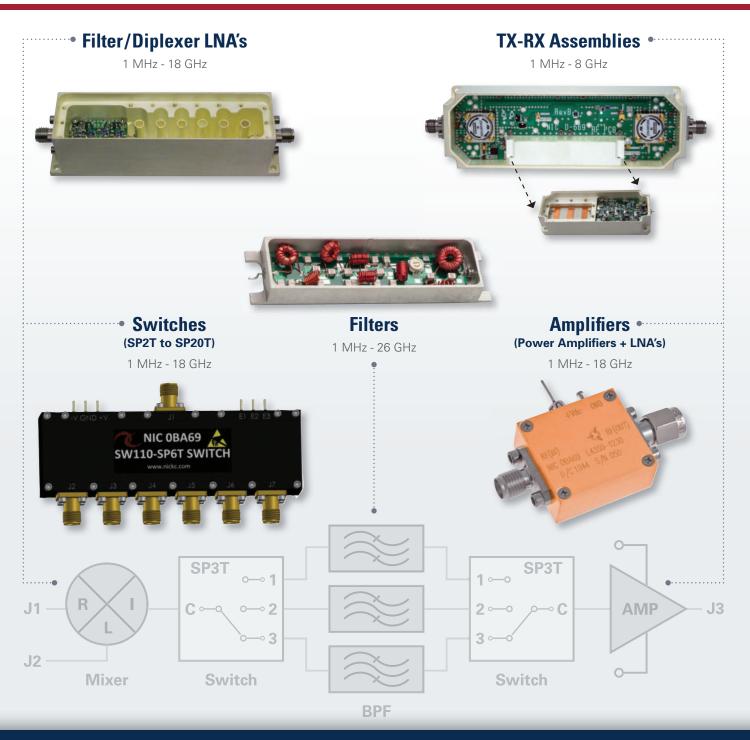






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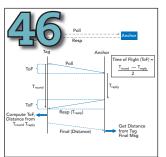


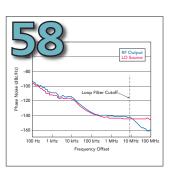
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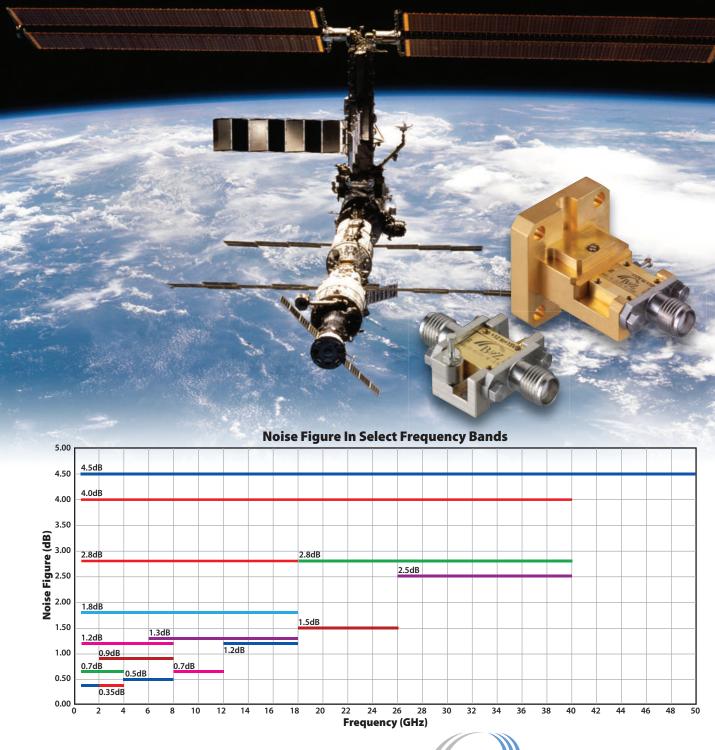
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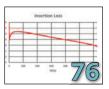
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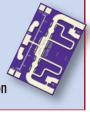
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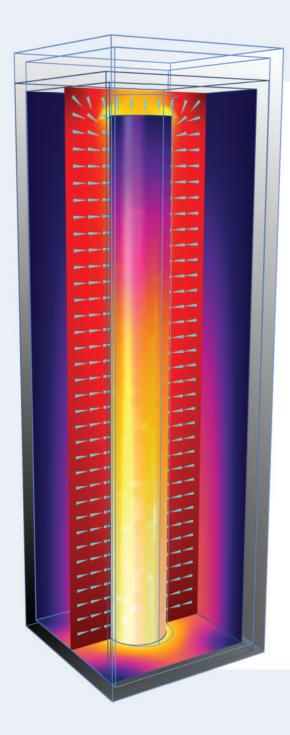


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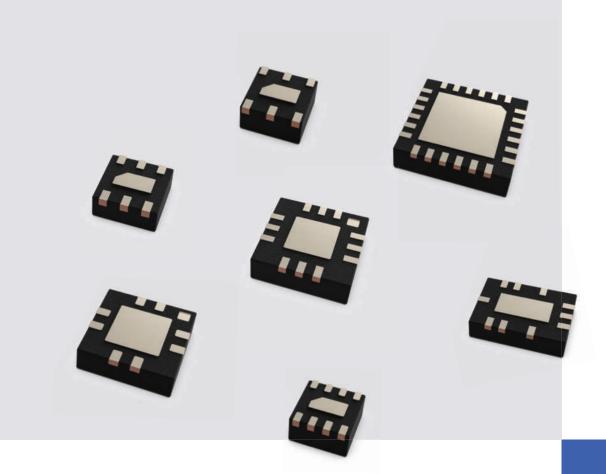
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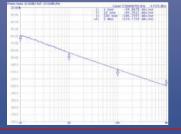
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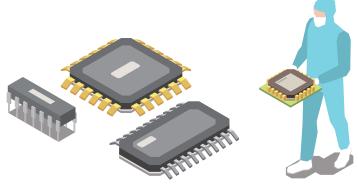
Model STF-06-S1-M operates from 110 to 170 GHz with a typical isolation of 23 dB. The mini isolator utilizes a novel magnetic design with precision machined housings to achieve a compact package size (0.75" x 0.75" x 0.55") and stable performance. It is ideal for subassemblies where space is at a premium. Other full band models available.











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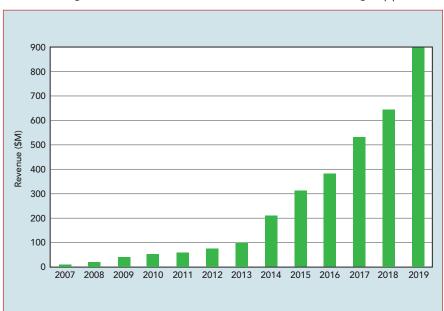
RF GaN: Trends and Directions

Eric Higham Strategy Analytics, Newton, Mass.

n the last decade, GaN has become an increasingly important technology for RF applications. The material properties of GaN enable devices with advantages in power density, form factor, breakdown voltage, thermal conductiv-

ity, operating frequency, bandwidth and efficiency. Designers have developed device solutions offering very compelling performance characteristics versus competitive semiconductor technologies.

The overwhelming application



▲ Fig. 1 RF GaN revenue, 2007–2019.

for GaN devices is power amplifiers (PAs), which take advantage of these benefits. Ongoing product development looks to take advantage of the unique material properties of GaN for other functions, primarily switches and low noise amplifiers. For the near future, however, PAs will dominate RF GaN revenue.

HOW DID WE GET HERE?

Strategy Analytics began tracking revenue in the RF GaN market in 2007 (see Figure 1). As with many compound semiconductor technologies, defense agencies were instrumental, providing early funding for device and process development, and defense applications served as early adopters of RF GaN devices. During the 2007 to 2013 period, roughly 85 percent of all RF GaN device revenue came from defense applications, with a spattering of GaN device adoption by commercial applications, primarily proof of concept and low volume applications.

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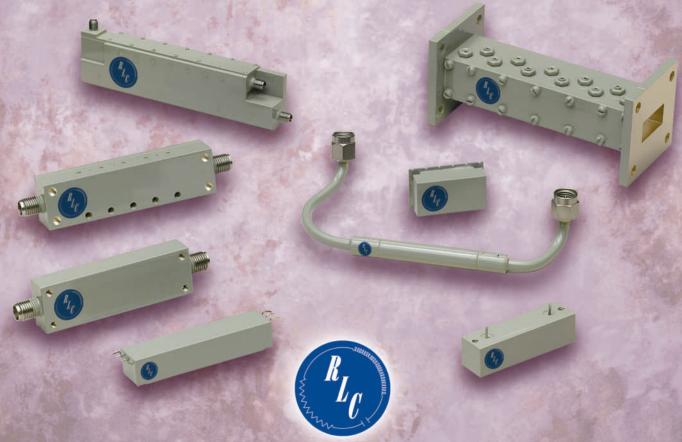
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Fig. 2 RF GaN revenue by market segment.

In 2013, RF GaN device revenue hit an inflection point and the trajectory of revenue growth increased dramatically. Much of the early proof of concept activity came from base station equipment manufacturers evaluating the reliability and performance characteristics of GaN PA devices for future designs. Chinese equipment manufacturers, particularly Huawei, became enthusiastic adopters of GaN technology for next-generation base stations. China's decision to rapidly deploy 4G LTE capabilities across the entire country fueled the ascension of Huawei as a global leader in base station equipment, and it drove a sharp uptick in RF GaN revenue beginning in 2014. As LTE deployments in China and the rest of the world approach saturation, the revenue growth from 4G has slowed; yet this dovetailed nicely with the emergence of 5G. Moving forward, 5G base station deployments will be the biggest growth engine for commercial RF GaN revenue.

Figure 2 shows the historical segmentation of RF GaN revenue. The importance of the base station segment is clear; what also should be clear is the robust growth of RF GaN revenue from defense applications. Shortly after the spike in 2014, RF GaN revenue in base stations surpassed revenue from de-

fense applications. Note, however, that the revenue from defense has increased 75x from 2007 to 2019 as GaN technology became a key enabler for evolving defense philosophies and battlefield strategies. If not for the extraordinary growth of base station applications, the story of the RF GaN market would have been its growth in defense.

The radar market presents the largest opportunity for RF GaN devices. Small, efficient PAs have made radars using active electronically scanned arrays (AESAs) "must haves" for next-generation and major retrofit programs in all domains. These solid-state AESA radars can generate and combine multiple scanning and tracking beams to offer significant performance and reliability advantages over traditional radar architectures.

Like their commercial counterparts, defense communication networks are managing more data traffic and moving higher in frequency in search of bandwidth. Battlefield engagements may involve forces from different nations, with different equipment and waveforms, constrained by the "on the move" aspect of a mission. Satellite equipment on the ground and in space serves as the linchpin for all these communications. The performance characteristics of RF GaN technology enable and supply flexibility for



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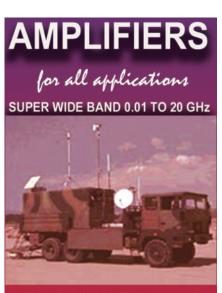
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AF0118273A		27	± 1.2	2.8
AF0118353A		35	± 1.5	3.0
AF0120183A	0.1 - 20	18	± 0.8	2.8
AF0120253A		25	± 1.2	2.8
AF0120323A		32	± 1.6	3.0
AF00118173A	0.01 - 18	17 ±1.0		3.0
AF00118253A		18 25 ±1.4		3.0
AF00118333A		33 ±1.8		3.0
AF00120173A	0.01 - 20	17	± 1.0	3.0
AF00120243A		24	± 1.5	3.0
AF00120313A		31	± 2.0	3.0

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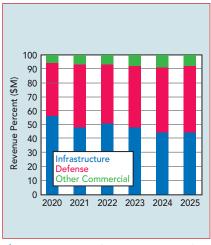
these requirements.

Electronic warfare (EW) is another important application for RF GaN. EW systems rely on broad bandwidth and high frequency ranges to detect targets and avoid detection by hostile forces. These applications require high RF transmit powers to disable or confuse enemy equipment. All these mission requirements fit nicely with the performance advantages of RF GaN.

THE FUTURE

Current geopolitical events are heavily influencing the future of the RF GaN market. To better understand this, we must explore the recent past. Industry insiders say Huawei has been buying electronic parts, particularly for base stations, since 2018. This was triggered by their expectation of tightening U.S. trade sanctions, which led to Huawei being placed on the "entity list," meaning an export license is required to supply products. Huawei's base station equipment market share, the purchases to inventory and their affinity for GaN PAs, drove a substantial bump in RF GaN revenue. As illustrated in Figure 2, from 2018 to 2020, RF GaN revenue for base stations more than doubled.

Of course, no discussion of 2020 is complete without noting the CO-VID pandemic. Global economies are struggling to regain footing, and the recovery has not been uniform. As the pandemic shut down economies, many people and businesses adopted a work-from-home model. Wireless and wireline networks became critical infrastructure. China has said that 5G will be a driving force behind the restart of their economy. As it is unlikely other regions of the world will let China get too far ahead with 5G, expect continuing 5G capital expenditures. Defense spending ties closely to economic growth, raising concerns about the effects of the pandemic on defense spending. As the defense goals of the new U.S. administration are still uncertain, there is also uncertainty about the likelihood of diverting defense spending to broader economic stimulus.



▲ Fig. 3 Projected RF GaN revenue by segment.

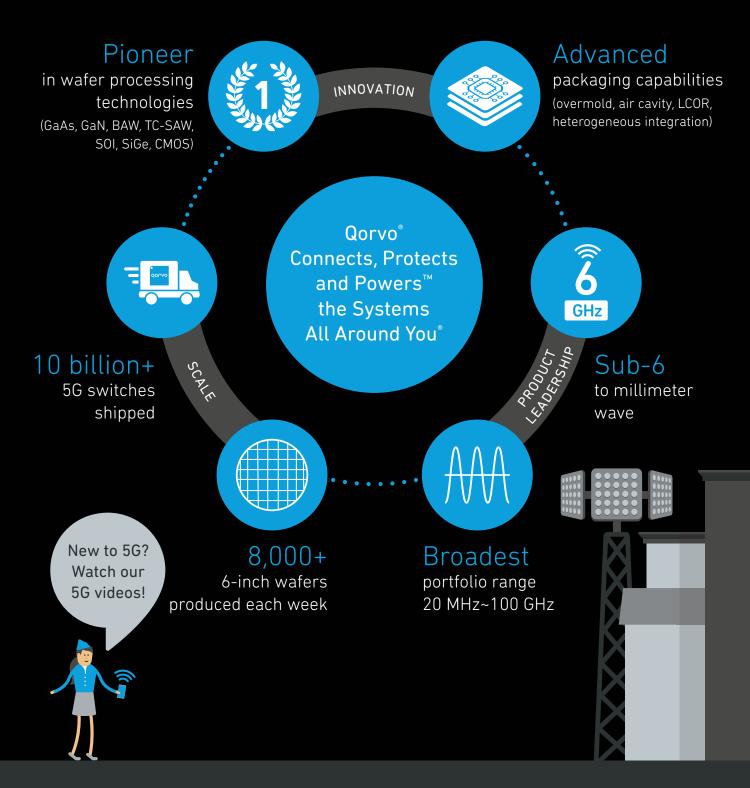
CONCLUSION

The adoption of RF GaN devices has increased dramatically in the last several years, with 2020 revenue crossing \$1 billion for the first time. Since 2018, RF GaN revenue increased by slightly more than 80 percent.

Challenges will influence the future growth trajectory of revenue. Deployments of 5G base stations will drive revenue growth, but China's timing for more 5G equipment purchases and how other regions respond to China are uncertainties. Defense spending, tied closely to economic growth, is also uncertain as global economies recover from the pandemic.

Despite these questions, we are still confident that RF GaN revenue will increase over the forecast period. Figure 3 shows our latest market segmentation forecast for RF GaN revenue. We expect steady revenue growth in defense, increasing the market share for this segment. Infrastructure revenue has grown so quickly because of Huawei's actions that we are forecasting a slight decline in revenue this year until mmWave deployments using GaN reinvigorate revenue growth. While the revenue from the "Other Commercial" segment is small, applications like VSAT, backhaul, CATV and, particularly, commercial satcom are gaining traction. We expect RF GaN revenue will approach \$2 billion in 2025, extending the GaN success story.

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Survey of RF GaN Fabs:Successful Commercialization and Global Supply

Gary Lerude, Microwave Journal Editor

eatured in this month's Microwave Journal, a survey of the major RF GaN fabs around the globe. The eight companies responding to our request for information offer an astounding 36 process variants (see the table on page 30), fabricating devices with 0.5 µm to 40 nm gate lengths on GaN on SiC, GaN on Si and GaN on diamond substrates. The process count does not include proprietary recipes the foundries maintain for their customers.

Since RF GaN became a topic at industry conferences in the mid-1990s,1 GaN has been commercialized, adopted primarily for military radar, electronic warfare and cellular base stations. One indication of the technology's success: GaN revenue reached \$1 billion in 2020, according to Strategy Analytics. Read more about the market development for GaN in the accompanying article by Eric Higham of Strategy Analytics (on page 22).

Eight GaN fabs responded to our survey:

- **HRL** Laboratories
- NXP
- **OMMIC**
- Qorvo
- **UMS**
- WIN Semiconductors
- Wolfspeed.

Six of the eight are based in the United States, two are in Europe and WIN Semiconductors is in Taiwan, All except for NXP are "open foundries," willing to engage with any customer-subject to export controls for the U.S. foundries.

Most GaN on SiC processes run on 100 mm wafers, although three of Qorvo's five processes and all NXP's are on 150 mm GaN on SiC wafers. Wolfspeed plans to migrate to 150 mm during the "next couple of years" as volumes increase. Although wafer diameter is often used as a marketing promotion. a loaded 100 mm fab is more cost efficient than a lightly loaded 150 mm fab. Interestingly, GCS' and OMMIC's GaN on Si processes use 150 mm wafers, which likely reflects the maturity and availability of silicon substrates.

While volume applications for RF GaN are below 20 GHz (e.g., phased array radar and sub-6 GHz base station power amplifiers), all the fabs surveyed have or are developing shorter gate length processes to extend device performance well into the mmWave frequencies, anticipating the capability of GaN to compete with GaAs and silicon for commercial and military applications at these higher frequencies.

In addition to offering competitive device performance, open foundries must support designers and their programs with design tools and test and packaging services. Alternatively, it could be test and packaging services and design tools. The survey identified the following capabilities:

GCS provides nonlinear device modeling and RF characterization, Silvaco device simulation, thermal analysis, failure analysis, 100 percent on-wafer DC test and die inking.



In addition to dedicated wafer fabrication, HRL Laboratories offers multi-project wafers for its mmWave T3 process, enabling prototype runs at reduced cost. HRL is a U.S. Department of Defense (DoD) Trusted Foundry and provides designers with process design kits (PDK) for Microwave Office and ADS.

OMMIC offers DC and RF on-wafer screening to deliver known-good die; visual inspection, including space grade for flight; reliability testing, including wafer and lot acceptance tests; environmental testing; and MMIC packaging.

Qorvo provides advanced packaging design, assembly and test for DoD programs, defense primes and commercial companies and meets the DoD's Trusted Cat 1A facility requirements.

UMS offers online design rule checking, RF on-wafer testing into mmWave frequencies (e.g., Sparameters, noise, power) and packaging options.

WIN Semiconductors can accommodate custom models, testing and offers various assembly interfaces.

Wolfspeed supports ADS and Microwave Office PDKs and provides DC and RF on-wafer probing.

All the fabs maintain reliability assurance programs to qualify new processes and monitor released processes for unexpected changes that could impair the reliability of devices fabricated on their lines.

Qorvo's GaN HEMT reliability qualification includes multi-temperature DC accelerated life testing (DCALT) and RF operational life testing, with reliability lifetime projections based on a failure criteria of less than a 10 percent change in Imax and using the 90 percent confidence lower bound for determining activation energy. Ongoing process monitoring consists of continuous DCALT monitoring using reliability test FETs on every wafer.

NXP's reliability qualification requirements include extended testing to 3x the expected lifetimes. Although most of NXP's GaN products are supplied to cellular base stations, the company's manufacturing operations are certified to the stringent automotive IATF16949 quality system standard.

For **OMMIC**, the final step in qualifying its GaN on Si processes is a space evaluation in collaboration with the European Space Agency.

Similarly, UMS' GaN processes are internally qualified to a minimum target of 20 years at 200°C, followed by space-level evaluation with outside space agencies.

WIN's GaN qualification follows industry test methods, with the results documented in qualification reports, available for review by customers.

The responses to Microwave Journal's survey reflect a strong global supply chain. These eight fabs are not the only suppliers of RF GaN devices: several "captive" fabs within defense primes serve their own programs, and compound semiconductor fabs are emerging in China (not included in this survey). RF GaN is clearly a strategic semiconductor technology.

Reference

1. R. J. Trew, M. W. Shin and V. Gatto, "Wide Bandgap Semiconductor Electronic Devices for High Frequency Applications," GaAs IC Symposium IEEE Gallium Arsenide Integrated Circuit Symposium, 18th Annual Technical Digest, 1996, pp. 6-9, doi: 10.1109/GAAS.1996.567625.

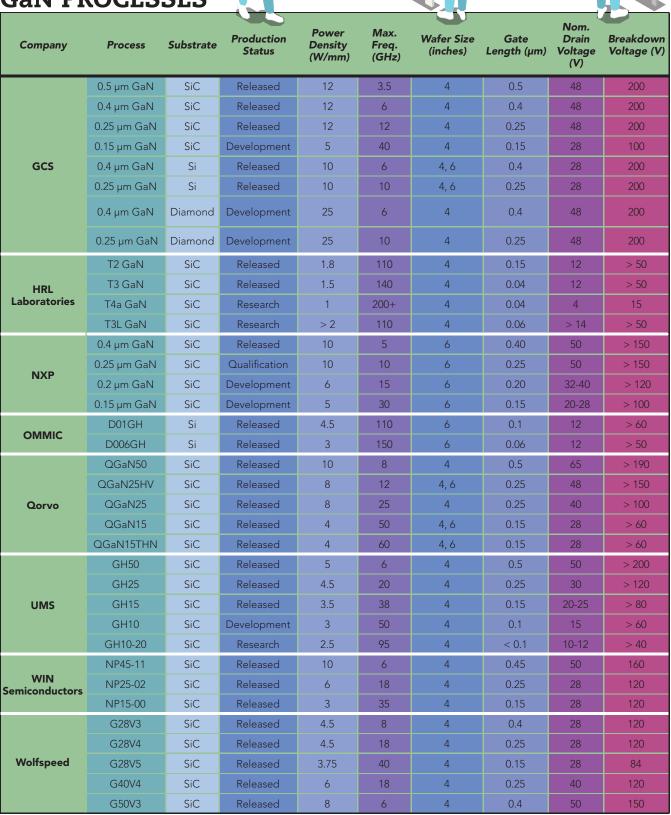
(Continued on page 30)





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HP0R5G-18G-CD-SFF https://www.pmi-rf.com/product-details/ hp0r5g-18g-cd-sff	0.5 - 18	0.5 GHz: 5 dB Max 1-16 GHz: 2 dB Max 18-16 GHz: 3 dB Max	40 dB Min @ 0.3 GHz	1.00" x 0.71" x 0.32" SMA (F) Removable
HP-118-CD-SFF https://www.pmi-rf.com/product-details/ hp-118-cd-sff	1 - 18	1 GHz: 4 dB Max 2-18 GHz: 2 dB Max	60 dB Min @ 0.5 GHz	1.00" x 0.71" x 0.32" SMA (F) Removable
HP2G-1780-CD-SS https://www.pmi-rf.com/product-details/ hp2g-1780-cd-ss	2 - 18	0.5 dB Typ	80 dBc @ 0.87 GHz	0.75" x 0.75" x 0.50" SMA (F) Removable
HP2G-1780-CD-SS-OPT2200 https://www.pmi-rf.com/product-details/ hp2g-1780-cd-ss-opt2200	2.5 - 18	0.5 dB Typ 1 dB Max	80 dB Min @ 0.87 GHz 30 dB Min @ 1.7 GHz	0.75" x 0.75" x 0.50" SMA (F)
HPF-4G18G-CD-SFF https://www.pmi-rf.com/product-details/ hpf-4g18g-cd-sff	6 - 18	1.5 dB Max	60 dB 1 - 2 GHz	1.43" x 0.79" x 0.50" SMA (F)
HP8G-7D8G-CD-SFF https://www.pmi-rf.com/product-details/ hp8g-7d8g-cd-sff	8 - 22	1.5 dB Max	35 dB Typ @ 7.5 GHz, 50 dB Min @ 5.6 GHz	1.15" x 0.70" x 0.50" SMA (F)
HP10G-9D7-CD-292FF https://www.pmi-rf.com/product-details/ hp10g-9d7-cd-292ff	10 - 27	1.5 dB Max	40 dBc @ 7 GHz	0.65" x 0.65" x 0.50" 2.92mm (F)
HPF18G-DC15G https://www.pmi-rf.com/product-details/ hpf18g-dc15g	18 - 26.5	1.5 dB Max	60 dB DC - 15 GHz	0.64" x 0.58" x 0.38" 2.92mm (F)
HP20G-19D5G-CD-292FF https://www.pmi-rf.com/product-details/ hp20g-19d5g-cd-292ff	20 - 40	1.5 dB Max	54 dBc @ 14.5 GHz	0.614" x 0.50" x 0.56" 2.92mm (F)
HP-26D5G-40G-CD-292FF https://www.pmi-rf.com/product-details/ hp-26d5g-40g-cd-292ff	26.5 - 40	2.0 dB Max	54 dBc Min @ 20 GHz	0.65" x 0.65" x 0.50" 2.92mm (F)











HPF-4G18G-CD-SFF

HP10G-9D7-CD-292FF

HPF18G-DC15G

HP20G-19D5G-CD-292FF HP-26D5G-40G-CD-292FF

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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		+20 dBm	2.0:1
		NOISE ANI	D MEDIÚM POV			2.0
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		+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		+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 / MAY 1 2 TVP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4		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
CAS0-5114 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
CA12157110 CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1
			TAVE BAND A		+31 ubili	2.0.1
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
CA0102-3111	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
CA0100-3110	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA0100 4112 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
CA20 4114 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		+34 dBm	2.0:1
LIMITING A		<i>L1</i>	J.U MAN, J.J 111	+24 /VIIIV	+34 ubili	2.0.1
Model No.		nnut Dynamic R	ange Output Power	Range Poat Powe	er Flatness dR	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dE	3m +7 to +1	1 dRm +	/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dE	Rm +14 to +1	18 dRm +	/- 1 5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dE	3m +14 to +1	18 dBm +, 19 dBm +,	/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0		3m +14 to +1	19 dBm +,	/- 1.5 MAX	2.0:1
AMPLIFIERS V			ATTENUATION	,		
Model No.	Freg (GHz)	Gain (dB) MIN	Noise Figure (dB) Pov	ver-out@P1-dB Gain	Attenuation Range	
CA001-2511A	0.025-0.150	21 5	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23 2	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28 2	2.5 MAX. 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24 2	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25 2	.2 MAX, I.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30 3		+18 MIN	20 dB MIN	1.85:1
LOW FREQUE		ERS				
Model No.		Gain (dB) MIN			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	+3 <u>3</u> 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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Cliff Drubin, Associate Technical Editor

Researchers Developing Tech to Mitigate Interference for Wideband RF Systems

he RF spectrum is a scarce resource that is becoming increasingly congested and contested as demand for spectrum access continues to grow. Within this crowded environment, the Department of Defense's (DoD) RF systems are hampered by mission-compromising interference from both self- and externally-generated signals. Wideband software-defined radio systems provide unprecedented access to the RF spectrum and are beginning to proliferate throughout the DoD and commercial applications as a result. Unfortunately, as bandwidth increases, dynamic range tends to decrease, which impacts the radio's sensitivity and performance.

To mitigate this challenge and support the continued use of these wideband radios, DARPA developed the Wideband Adaptive RF Protection (WARP) program. WARP is exploring the development of tunable filters to manage external interference as well as tunable signal canceller architectures to address self-interference. The goal is to develop technologies that are tunable over wide bandwidths with low-loss and high linearity that can protect defense and commercial wideband systems.

DARPA recently announced the research teams selected to tackle WARP's R&D objectives. These teams will explore a diverse set of technology approaches that include intrinsically-switched electromagnetic (EM) resonators, multiferroics, acoustics and photonics, which will all come together with new circuit architectures, heterogeneous device integration and advanced RF packaging. The technical approaches will also include embedded sensing of the EM spectrum, which provides adaptive control of the tuning elements and enables the hardware to react to environmental changes.

WARP is divided into two primary research areas. The first focuses on the development of new filter architectures that have inherently wideband tuning characteristics to cover the 2 to 18 GHz band of interest. The second research area focuses on reconfigurable signal cancellers in the 0.1 to 6 GHz band of interest while supporting large time delay spreads to handle dispersive signal leakage paths.

5th Gen to 5th Gen Communications Across Domains

ockheed Martin Skunk Works®, the Missile Defense Agency and the U.S. Air Force successfully linked a U-2, five F-35s and an F-22 in air and provided real-time 5th Generation data to operators on the ground, introducing greater mission

flexibility across domains and an enhanced total operational picture for the joint warfighter.

Named Project Hydra, the latest flight test leveraged an open systems gateway payload aboard the U-2 to connect the F-22 to the F-35s via native intra-flight data link and multifunction advanced data link, success-



Project Hydra (Source: Lockheed Martin)

fully sharing data between all airborne aircraft and with nodes on the ground. The target tracks were also transmitted by and through the U-2 into the fighter avionics and pilot displays.

"Project Hydra marks the first time

that bidirectional communications were established between 5th Generation aircraft in-flight while also sharing operational and sensor data down to ground operators for real-time capability," said Jeff Babione, vice president and general manager of Lockheed Martin Skunk Works®. "This next-level connectivity reduces the data-to-decision timeline from minutes to seconds, which is critical in fighting today's adversaries and advanced threats."

The Project Hydra effort also marked the first time F-35 sensor data was delivered to an operational ground system over a tactical targeting network terminal (TTNT) link using an airborne gateway. This data was then sent to the U.S. Army Integrated Battle Command System (IBCS) airborne sensor adaptation kit (A-Kit), also developed by Lockheed Martin. The A-Kit then transmitted data to the IBCS Tactical System Integration Laboratory at Fort Bliss, Texas. IBCS used the F-35 sensor data to conduct a simulated Army fires exercise.

The core of the Hydra payload leverages the open mission systems compliant Enterprise Mission Computer 2, facilitating F-22, F-35, TTNT and Link-16 connections. By leveraging both line-of-sight and beyond line-of-sight datalink capabilities of the U-2, data can now be shared directly to tactical users and globally to command and control (C2) nodes like the Common Mission Control Center (CMCC). During this demonstration, both the CMCC and Shadow Operations Center at Nellis Air Force Base were able to view the sensor and platform data to enable situational awareness for operational command and control of highly capable air assets.

Protection for Blue, Green and Brown Water Navies



heinmetall is currently celebrating an anniversary in the field of maritime protection systems; the Rheinmetall Waffe Muni-

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DefenseNews

tion GmbH's Fronau branch delivered the 300th Multi Ammunition Softkill System (MASS). The customer, the Finnish Navy, was also the system's first customer. Launched onto the market in 2002, MASS is now in service with no fewer than 14 user nations.

Rheinmetall's MASS family of ship protection systems is suitable for use by blue, green and brown water navies. It protects ships and boats against a wide range of threats—on the high seas as well as in coastal waters or on rivers. The fully automated MASS decoy system offers a unique degree of protection against modern, sensorguided missiles, covering all relevant wavelengths of the electromagnetic spectrum. MASS can be installed on any type of vessel. Moreover, it can be integrated into an existing combat management system or operate as a standalone system. Ordinarily, MASS consists of between one and six trainable launchers. Each launcher can fire 32 OmniTrap special effect charges. Each launcher comes with a control unit and a data interface.

Rheinmetall has steadily expanded its family of MASS ship protection systems. Two new variants are the MASS OCR with off-board corner reflector and the new standalone version MASS_ISS with an integrated sensor suite for units that lack an independent capability for detecting laser and radar threats.

The MASS_OCR version features special deception

and diversion capabilities. Each launcher is armed with two off-board corner rockets that produce ship-like radar signatures. Programmed for a range of between 35 and 850 meters, the effects they produce last for over 60 seconds.

Developed especially for vessels without organic shipboard reconnaissance systems, Rheinmetall's



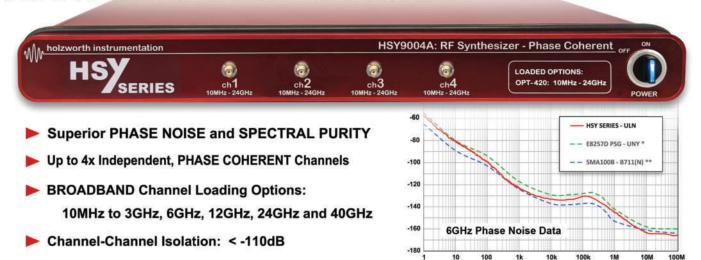
MASS (Source: Rheinmetall AG)

MASS ISS is a standalone system with an integrated sensor suite. Forming an integral part of the MASS_ISS system complex, the REKa-50, which stands for "Rheinmetall ESM Ka-Band," assures reliable detection and

effective engagement of threats in the mmWave radar frequency range. Moreover, Rheinmetall is a onestop-shop supplier, producing the decoy systems, the decoy munitions as well as providing and integrating the sensors. The number of launchers is scalable. All are linked together and controlled by Rheinmetall's firing algorithms. It also includes a sensor system with radar and laser warning sensors, a tactical control unit and a power supply.

REAKING NEWS:

NEW RF SYNTHESIZER BREAKS THE BARRIER OF HIGH PERFORMANCE AND **HIGH CHANNEL DENSITY.**





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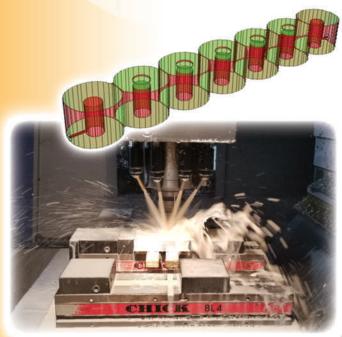
10k

3.2GHz-10GHz data provided at www.keysight.com
 6GHz data provided at www.rohde-schwarz.com

www.holzworth.com

Reactel, Incorporated

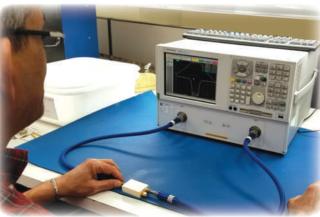
Solving your most complex filter problems.



DESIGN

To MANUFACTURING

TESTING

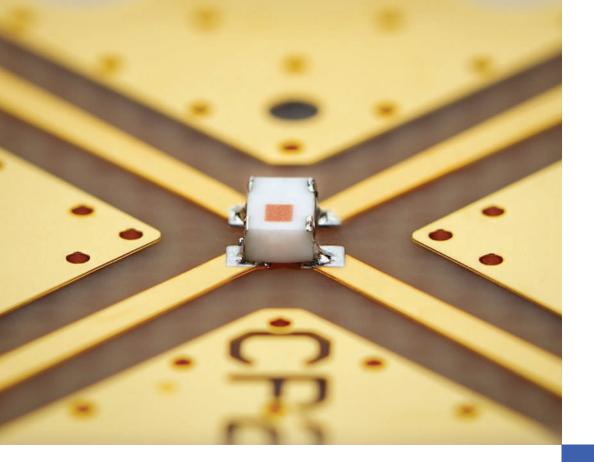












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CommercialMarket

Cliff Drubin, Associate Technical Editor



he demand for broadband connectivity over both fixed and mobile broadband networks is increasing dramatically. Yet, despite network expansions and upgrades, only half of households worldwide currently have access to fixed broadband services. With the rollout of low earth orbit (LEO) constellations, satellite broadband services will improve broadband penetration significantly. ABI Research forecasts that the satellite broadband market will reach 3.5 million subscribers in 2021, grow at a CAGR percent to reach 5.2 million users in 2026 and generate US\$4.1 billion service revenue.

"LEO satellites will play an important role in satellite broadband services in the years to come. High throughput satellite (HTS) LEO systems can support multi-Gbps speed per satellite. Orbiting around 800 to 1,600 km from the earth's surface, LEO systems offer a major advantage of low latency between 30 to 50 milliseconds, enabling LEO broadband services to support low latency services such as online gaming and live video streaming," explained Khin Sandi Lynn, industry analyst at ABI Research.

Traditionally, geostationary earth orbit (GEO) satellites are mainly used to provide broadband services to homes and businesses in remote or rural areas where the deployment of mobile or fixed broadband connectivity is challenging. Although GEO satellites support viable speed over 100 Mbps speed broadband access, their distance from the earth's surface, about 36,000 km, creates a drawback of longer latency as high as 600 ms, limiting the use of low latency applications.

LEO satellite operator SpaceX first launched its Starlink broadband services to residential users in 2020, supporting 100 Mbps broadband speed with unlimited data caps per month. SpaceX has launched over 1,000 LEO satellites and aims to serve more than 600,000 homes and businesses in the U.S. The company is now working toward the expansion of its broadband service to some markets in Latin America. Other companies such as One-Web and Telesat have launched LEO satellites providing connectivity to the business segment. Amazon, which plans to launch LEO constellations named project Kupier, received Federal Communications Commission (FCC) approval for its project in mid-2020, although the first satellite launch date is yet to be confirmed.

As broadband connectivity is becoming an essential service in today's homes, satellite broadband services will remain an important part of the broadband market. There is inevitable competition from terrestrial broadband networks due to the expansion of fixed broadband networks and mobile networks. The expansion of

LTE and 5G networks will challenge the satellite broadband industry by supplying fixed wireless access services to residential users. However, the cost and time associated with terrestrial network deployments can limit distribution in remote areas.

Commercial 6G Deployments Could Start as Early as 2028, Standards Expected in 2026

any countries worldwide have deployed their 5G networks, with leading countries including South Korea, China, the U.S., the U.K., Saudi Arabia, Finland, Spain, the United Arab Emirates, Australia and Germany. Alongside these deployment activities, academia and industry are starting to envision the sixth generation (6G) of wireless technology for the 2030s, and many related research projects have already started. According to the time frames of previous wireless network deployments, ABI Research forecasts that 2028 and 2029 will be the early commercial deployment years for 6G, with the first standard technology expected around 2026.

"X reality (XR), which is a combination of augmented reality, virtual reality and mixed reality, is a promising solution for 6G to create a mixed real and virtual environment with either real-time or non-real-time human-machine interaction," said 5G & Mobile Network Infrastructure Senior Analyst at ABI Research, Jiancao Hou. "Self-organization and self-healing capabilities of a network to support autonomous driving, drone swarming and pervasive networking are also critical to reduce the time and cost of network deployment and offer greater mobile coverage." Moreover, "In the 2030s, 6G could be the key enabler to realizing ubiquitous connectivity with a wide range of devices/sensors used in diverse communication environments," Hou concluded.

5G is designed to provide a peak data rate of 20 Gbps with an average user experience rate of 120 Mbps. These numbers probably need to be revised to 1,000 Gbps and 1 Gbps, respectively, in 6G to support applications like XR and holographic communications, where THz communications can play a vital role due to its extremely wide bandwidth. In-band full-duplex technology enables communication nodes to learn or sense other available channels while transmitting data, which shortens the latency and improve spectrum efficiency. Artificial intelligence (AI) and machine learning technology have already been a hot topic in the 5G era. By combining with distributed computing, the rapid growth of data volume and highly complex network architecture foreseen in 6G are expected to be easily processed and managed to meet dynamic connectivity needs.

For More Information

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CommercialMarket

5G for 12 GHz Coalition Launches to Unleash the Power of Mid-Band Spectrum

ver 20 prominent public interest groups, trade associations and companies in the telecommunications sector launched the 5G for 12 GHz Coalition, urging the FCC to act swiftly and modernize old rules to allow the critical capacity in the 12 GHz spectrum band to be utilized for 5G.

Reliable, affordable connectivity is essential for almost every aspect of modern life. The 500 MHz of available capacity in the 12 GHz band offers the promise of connecting Americans to next-generation technologies while protecting existing services. By unlocking the power of 5G, students will have more tools to excel in the classroom, patients will have more access to critical health care services and small-business owners will have more opportunities to tap into new marketplaces. Once approved by the FCC, this vital swath of spectrum can be deployed immediately for terrestrial, two-way 5G services.

"America has a historic opportunity to immediately unleash the power of the 12 GHz band for 5G, and the members of this Coalition are linking arms to call for much-needed, swift action. This will ensure our nation's position as a global leader, enhance broadband infrastructure and availability, expand consumer choice, and drive innovation," said Chip Pickering, co-chair of the

Coalition and CEO of INCOMPAS, one of the Coalition's founding members. "The spectrum-sharing environment has changed dramatically since the rules governing this spectrum were enacted in the pre-iPhone era. The FCC has an opportunity to enhance U.S. leadership in 5G and strengthen key economic and national security interests."

Though the FCC has taken some action to bolster connectivity for consumers and open more mid-band spectrum, the U.S. is still losing the 5G race to China, ranking last among 13 major wireless markets. Opening the 12 GHz band would immediately propel the U.S.

Coalition urges the FCC to double U.S. licensed mid-band spectrum, supercharging 5G deployment while protecting existing services.

position in available 5G mid-band spectrum, eclipsing China's spectrum deployment and helping cement U.S. global competitiveness.

The Coalition calls on the FCC to act swiftly on its Notice of Proposed Rulemaking (expanding flexible use of the 12.2 to 12.7 GHz Band, et al., WT Docket No. 20-443, et al.) to allow the 12 GHz band to unlock the power of 5G for all Americans.



HRL LABORATORIES IS OPENING UP ACCESS TO ITS RF GaN MMIC TECHNOLOGY (T3 GaN) THROUGH MULTI-PROJECT WAFER (MPW) SERVICES FOR EARLY ACCESS PROTOTYPING.

T3 GaN is a leading-edge mm-wave GaN HEMT technology with a 40 nm gate length with a high cut-off frequency (Ft = 200 GHz)

2 Process Design Kits available for circuit design (Cadence Microwave Office AWR & Keysight ADS)

A minimum of 4 MPW starts per year available

MMIC technology suitable for power amplifiers, low noise amplifiers, switches, mixers, and designs up to G-band



HRL LABORATORIES, LLC, HAS SCHEDULED QUARTERLY MULTI-PROJECT WAFER RUNS IN 2021 AND 2022 FOR ITS T3 Gan MMIC technology. Details are available at www.hrl.com/products-services/foundry or ganmpw@hrl.com



A History of Proving that Performance Barriers are Made to be **SHATTERED**

1998

Support for US Army Longbow Missile Program with high performance carrier mixer



2002

4-lag correlator for ASIAA to detect "big bang" radiation



2007

Dr. Christopher Marki joins to develop new and complementary product lines



2016

- Dr. Christopher Marki becomes CEO
- · 10,000 square foot expansion to support unprecedented growth
- · Release of MMIC IQ Mixers, Nonlinear Transmission lines, Equalizers & Diode Limiters

2018

Release of over 50 new products including Marki's first space-grade MMIC product



Expansion to a 60,000 square foot facility in Morgan Hill

1991

Marki Microwave is founded by Ferenc and Christine Marki



2000

Purchase of 10,000 square-foot space for headquarters and manufacturing in Morgan Hill, CA



Introduction of the T3 Mixer - Still the best mixer on the planet



2013

Introduction of the Microlithic mixer solving the mixer paradox

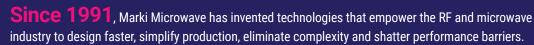
2017

- Company grows past 100 employees
- Accelerating the innovation in MMIC mixers with the world's first MMIC T3 mixer, broadband triple-balanced MMIC mixer and multi-octave MMIC mixer



2020

Breaking 100GHz barrier and safely maintained production throughout COVID-19







MERGERS & ACQUISITIONS

NI announced it has acquired monoDrive, an ultrahigh fidelity simulation software provider for advanced driver-assistance systems (ADAS) and autonomous vehicle development. The acquisition expands NI's reach in ADAS and simulation markets and will enable NI's transportation customers to accelerate the development, test and deployment of safer autonomous systems. NI will leverage monoDrive's expertise in signal processing and advanced simulation to help customers accelerate the delivery of ADAS through high fidelity driving environments capable of modeling numerous sensors and thousands of real-time scenarios. This approach combined with NI's software-connected systems will help transportation customers streamline the transitions between simulation, lab-based and physical testing environments.

AMETEK announced that it has acquired NSI-MI Technologies for \$230 million. NSI-MI Technologies is a provider of RF and microwave test and measurement solutions and services with annual sales of approximately \$90 million. NSI-MI's expertise in advanced RF and microwave technologies allows them to provide complete test and measurement systems for niche applications across the aerospace, defense, automotive, wireless communications and research markets. The company has a diverse portfolio of testing instrumentation, components and software, while also providing customers with turnkey anechoic and simulation chambers, and a broad set of aftermarket services.

Skyworks Solutions Inc. announced that it has entered into a definitive agreement with Silicon Laboratories Inc., a provider of silicon, software and solutions for a smarter, more connected world, under which Skyworks will acquire the Infrastructure & Automotive business of Silicon Labs in an all-cash asset transaction valued at \$2.75 billion. The acquisition will accelerate Skyworks' expansion into the industry's most important growth segments, including electric and hybrid vehicles, industrial and motor control, power supply, 5G wireless infrastructure, optical data communication, data center, automotive, smart home and several other applications. Skyworks will be uniquely positioned to address a combined market opportunity approaching \$20 billion annually.

COLLABORATIONS

CAES and Colorado Engineering Inc (CEI) have announced a strategic alliance to jointly develop advanced technology for missile seekers, datalinks, electronic warfare systems, next-generation radar and communications systems. The strategic alliance allows for the CAES and CEI engineering teams to agilely collaborate on critical projects for aerospace and defense customers. With

this alliance, aerospace and defense prime contractors and the government will benefit from the team's newly combined advanced systems engineering, and volume manufacturing expertise, combining both digital and analog functionality and thus allowing for more effective engagements earlier in the life cycle of a program.

NEW STARTS

Richardson RFPD Inc., an Arrow Electronics company, announced a new service with Fractus Antennas. The Fractus Antennas for Richardson RFPD Kick-Start Service offers a customized antenna design recommendation to accelerate time-to-market for IoT projects. The Kick-Start service includes a Fractus Antennas Virtual AntennaTM product selection to meet device and application specifications, recommended antenna location information to achieve maximum performance, additional antenna integration tips and set-up analysis for matching network topology, reflection coefficient and estimated efficiency. Fractus Antennas' Virtual Antenna technology includes the mXTEND family of antenna boosters that have been specifically designed to provide multiband performance in wireless devices.

ACHIEVEMENTS

Analog Devices Inc. (ADI) has received a BAE Systems Partner 2 Win Supplier of the Year Award. ADI was named the Original Component Manufacturer of the Year for exceptional performance and contributions to supply chain success in 2020 for BAE Systems, Inc.'s Electronic Systems sector. BAE Systems' Partner 2 Win program is designed to achieve operational excellence and eliminate defects in its supply chain by raising the bar of performance expectations to meet the demand of current and future customers. As part of the program, BAE Systems meets regularly with its suppliers to transfer best practices to ensure that the components and materials that compose BAE Systems products meet the highest-quality standards.

The Global Certification Forum (GCF) has approved the first two radio resource management (RRM) conformance test cases for 5G FR2 frequencies, implemented on the R&S TS-RRM-NR 5G RRM conformance test system from Rohde & Schwarz. The test cases have been validated in seven FR2 and LTE band combinations. With this success, Rohde & Schwarz is leading the way in validated test cases for the technically challenging FR2 mmWave frequency bands. Conformance tests are vital for mobile communications technology as mobile network operators worldwide rely on the GCF conformance certification to accept mobile devices in their networks

NXT Communications Corp. announced that **Technology Association of Georgia** has named NXTCOMM Innovation Company of the Year – Startup. David Horton, CEO, accepted the award during a live-streamed Technology Awards ceremony on the first day of the Georgia Technology Summit. A total of eight companies and individuals throughout the state were recog-

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Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] ◊	Amplitude Unbalance (dB) [Typ:/Max.]	Phase Unbalance (Deg.) [Typ./Max.]	Isolation (dB) [Typ:/Min.]	VSWR (Typ.)	Input Power (Watts) [Max.] =	Package
2-WAY							,	
CSBK260S	20 - 600	0.28 / 0.4	0.05 / 0.4	0.8/3.0	25 / 20	1.15:1	50	377
DSK-729S	800 - 2200	0.5/0.8	0.05/0.4	1/2	25 / 20	1.3:1	10	215
DSK-H3N	800 - 2400	0.5 / 0.8	0.25 / 0.5	1/4	23 / 18	1.5:1	30	220
P2D100800	1000 - 8000	0.6 / 1.1	0.05/0.2	1/2	28 / 22	1.2:1	2	329
DSK100800	1000 - 8000	0.6 / 1.1	0.05/0.2	1/2	28 / 22	1.2:1	20	330
DHK-H1N	1700 - 2200	0.3 / 0.4	0.1/0.3	1/3	20 / 18	1.3:1	100	220
P2D180900L	1800 - 9000	0.4/0.8	0.05 / 0.2	1/2	27 / 23	1.2:1	2	331
DSK180900	1800 - 9000	0.4 / 0.8	0.05/0.2	1/2	27 / 23	1.2.1	20	330
3-WAY							1	
S3D1723	1700 - 2300	0.2/0.35	0.3/0.6	2/3	22 / 16	1.3:1	5	316
4-WAY	T.							
CSDK3100S	30 - 1000	0.7 / 1.1	0.05/0.2	0.3/2.0	28 / 20	1.15:1	5	169S
With matched oper	ating conditions							

HYBRIDS Z



Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] 0	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ:/Max.]	Isolation (dB) [Typ:/Min.]	VSWR (Typ.)	Input Power (Watts) [Max.]	Package
90°								
DQS-30-90	30-90	0.3 / 0.6	0.8 / 1.2	1/3	23 / 18	1.35:1	25	102SLF
DQS-3-11-10	30 - 110	0.5 / 0.8	0.6/0.9	1/3	30 / 20	1.30:1	10	102SLF
DQS-30-450	30 - 450	1.2 / 1.7	1 / 1.5	4/6	23 / 18	1.40:1	5	102SLF
DQS-118-174	118 - 174	0.3 / 0.6	0.4 / 1	1/3	23 / 18	1.35:1	25	102SLF
DQK80300	800 - 3000	0.2/0.4	0.5 / 0.8	2/5	20 / 18	1.30:1	40	113LF
MSQ80300	800 - 3000	0.2/0.4	0.5 / 0.8	2/5	20 / 18	1.30:1	40	325
DQK100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1/4	22 / 20	1.20:1	40	326
MSQ100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1/4	22 / 20	1.20:1	40	346
MSQ-8012	800 - 1200	0.2/0.3	0.2/0,4	2/3	22 / 18	1.20:1	50	226
180° (4-PORTS)							
DJS-345	30 - 450	0.75 / 1.2	0.3 / 0.8	2.5/4	23 / 18	1.25:1	5	301LF-1
In excess of theore	tical counting lose of	0.40						

COUPLERS CHE



Model #	Frequency (MHz)	Coupling (dB) [Nom]	Coupling Flatness (dB)	Mainline Loss (dB) [Typ:/Max.]	Directivity (dB) [Typ./Min.]	Input Power (Watts) [Max.] =	Package
KFK-10-1200	10 - 1200	40 ±1.0	±1.5	0.4 / 0.5	22 / 14	150	376
KDS-30-30	30 - 512	27.5 ±0.8	±0.75	0.2 / 0.28	23 / 15	50	255 *
KBS-10-225	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	255 *
KDS-20-225	225 - 400	20 ±1.0	±0.5	0.2/0.4	25 / 18	50	255 *
KBK-10-225N	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	110N *
KDK-20-225N	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	110N *
KEK-704H	850 - 960	30 ±0.75	±0.25	0.08 / 0.2	38 / 30	500	207
SCS100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8/5	25	361
KBK100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8/5	25	322
SCS100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1.0	14/5	25	321
KDK100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1.0	14 / 5	25	322
SCS100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	12/5	25	321
KDK100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	14/5	25	322
KEK-1317	13000 - 17000	30 ±1.0	±0.5	0.4 / 0.6	30 / 15	30	387

Add suffix - LF to the part number for RoHS compliant version. With matched operating conditions

Unless noted, products are RoHS compliant.



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Around the Circuit

nized for making an impact in 2020. Individuals were recognized for inspiring their teams, leading innovation and delivering value within their organization or industry, while winning companies were honored for developing innovative technology solutions that stood out in any industry.

W. L. Gore & Associates announced it was named a Silver Supplier for exceptional performance and contributions to supply chain success in 2020 by BAE Systems' Electronic Systems sector. Gore, which provides a variety of wire and cable components for BAE Systems, was honored by them at a virtual ceremony following selection from a diverse pool of suppliers.

CONTRACTS

Sensor systems supplier **HENSOLDT** has been awarded a contract worth approximately 200 million euros under the 'Quadriga' procurement program of 38 Eurofighter/ Typhoon combat aircrafts by the **German Air Force**. The contract placed by Airbus Defence and Space comprises production and delivery of radar systems and core electronics components which will be produced at HENSOLDT's site in Ulm, Germany, and at consortium partner Indra's site in Spain. The new radar is based on state-of-the-art active electronically scanned array technology. In contrast to conventional systems with a

purely mechanically rotating antenna, the radar beam is electronically controlled by a multitude of individual transmit/receive modules.

EM Solutions, a subsidiary of Electro Optic Systems Holdings, has completed the shipment of its final Cobra terminal for the Royal Australian Navy's (RAN) Anzac Class Frigates. Witnessing the over-the-air test of the final and eighth Cobra terminal for the Navy's Anzac frigates was Chief of Navy, Vice Admiral Michael Noonan, AO and Dr. Rowan Gilmore, CEO, EM Solutions. The Cobra is now used by the RAN on its Cape Class, Supply, Anzac and future Arafura-class ships, as well as by five other navies around the world. On the Anzac frigates, the Cobra will provide quality of life services to the crew and additional services to its existing legacy communications systems.

Smiths Interconnect, a provider of technically differentiated multi-function RF systems, subsystems, antennas, RF and MW components, connectors and cable assemblies for aerospace and defense, announced receipt of a contract from Mitsubishi Electric Corp. to participate in the development of a G-Band satellite for the Japan Aerospace Exploration Agency. Smiths Interconnect will design a component with a dual-band mmWave antenna and receivers as a part of the advanced microwave scanning radiometer 3 (AMSR3). The AMSR3 is designed to receive microwave radiation from the earth and will be mounted on the Global Observing SATellite for Greenhouse gases and Water cycle.

Global Communication Semiconductors





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0.15, 0.25 & 0.4um GaN Foundry Technology:

Processes	Operations	Features	Performance
GaN/Si	5-20V	Wide bandwidth & cost effective (6")	5V, 71% PAE @ 6 GHz
GaN/SiC	28 & 48V	High power & efficiency	55% PAE @ 30 GHz
GaN/Diamond	Up to 100V	Excellent thermal conductivity	23W/mm

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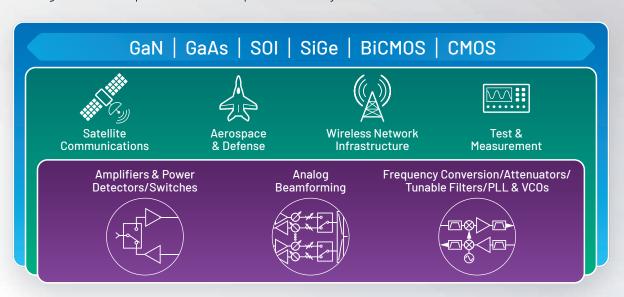




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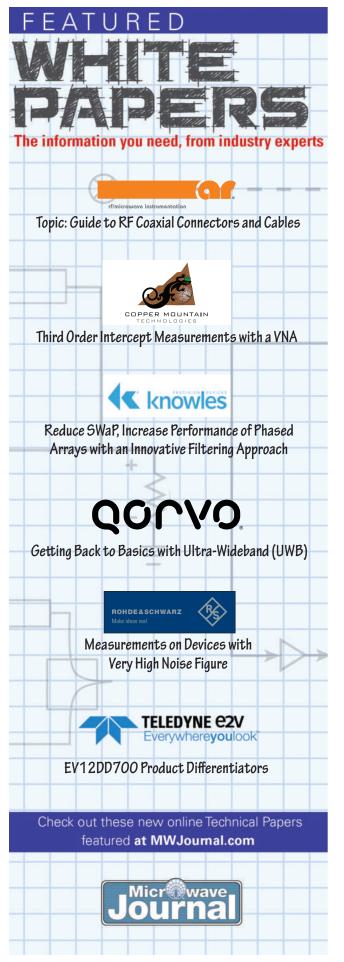


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Around the Circuit

PEOPLE



▲ Dr. James C. Rautio

Sonnet has announced that their founder, **Dr. James C. Rautio**, has been elected a Fellow of the Royal Society of Edinburgh. This honor acknowledges his four decades of contributions to the field of electromagnetics as well as his extensive efforts promoting and preserving the history of James Clerk Maxwell. This includes preservation of Maxwell's home, Glenlair, which was near col-

lapse, as well as giving over 150 presentations and publishing numerous papers on the life of Maxwell. Dr. Rautio's contributions to electromagnetics are summarized in over 100 peer-reviewed papers as well as his recent book, "Method of Moments Analysis of Structures Embedded in Shielded Layered Media."



▲ Leonard Pelletier

RFMW announced the addition of a new business development manager for the Americas specializing in RF power applications support. **Leonard Pelletier** is a high energy, creative engineering expert on RF power amplifier design and RF component applications. Pelletier's substantial background comes from his experience working for a major RF power semi-

conductor manufacturer that specializes in LDMOS, GaN and SiGe device technologies where he worked in both design and technical support functions. Author, manager, trainer and public speaker, Pelletier was personally instrumental in the transition from bipolar devices to the use of LDMOS technology by cellular infrastructure OEMs over 25 years ago.

REP APPOINTMENTS

Infinite Electronics, a global supplier of electronic components, has added EPI Vietnam as a distributor for Vietnam. EPI Vietnam Technologies Co. Ltd. was founded in 2013 with a vision to be a market leader in electronic component distribution in Vietnam. In addition to providing access to thousands of components and assemblies, EPI offers engineering services to help its customers develop solutions from concept through the design process, all the way to manufacture. EPI serves a wide range of industries and sectors including, industrial, consumer, automotive and telecom.

PLACES

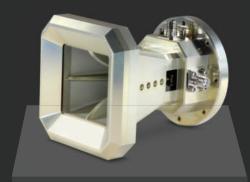
Verus® Research announced the expansion and buildout of a new research facility. The fast-growing technology company will move into an empty big-box retail space in Albuquerque, N.M., in August. In addition to the new 41,240 square feet of research and office space, Verus Research will maintain its multi-floor headquarters in Albuquerque as well as its two other lab and office spaces throughout the city.



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Exploring Ultra-Wideband Technology for Micro-Location-Based Services

Mickael Viot, Alexis Bizalion and Jervais Seegars Qorvo, Greensboro, N.C.

Ultra-wideband (UWB) is an IEEE 802.15.4a/z standard radio technology that can measure distance and location with unprecedented accuracy—within a few centimeters—by calculating the time it takes radio signals to travel between devices. It is uniquely suited to a new generation of micro-location-based systems that require secure real-time positioning information, indoors or outdoors. The standard was also designed with low-power and low-cost in mind and with the requirement to support large numbers of connected devices. UWB operates in regulated unlicensed spectrum and coexists with other wireless technologies using the same spectrum. UWB is on the brink of mass adoption; it has been incorporated into leading smartphones and many other devices and, ultimately, may become as ubiquitous as Wi-Fi and Bluetooth® Low Energy (BLE).

oday, it's hard to imagine life without easily navigating anywhere in the world—both indoors and outdoors. GPS, popularized in the 1990s, was a huge advance in location technology and changed our lives. It allowed users to electronically locate the nearest gas station, track fitness, map out travel plans and find the way home. It has helped companies increase efficiency and build new business models. Without GPS, how would e-commerce companies efficiently navigate deliveries to your doorstep?

Ten years later, another breakthrough brought navigation inside, aptly called indoor navigation or positioning. Think Google Maps for malls, airports and other large buildings. When designing these first indoor location systems, engineers used the technologies widely available at the time, usually Wi-Fi and BLE. Though these technologies are excellent for data communications, they're only capable of determining location within a few meters.

Now we're seeing the rise of micro-location-based systems that have much greater precision. People and businesses want to be able to locate and find pretty much anything in real-time, whatever its size. Let's say you're

at home and have misplaced your car keys or TV remote control, or you're in a grocery store and can't find your favorite brand of coffee, or you're in a hospital urgently trying to find the infusion pump in an emergency. UWB is uniquely capable of supporting these micro-location applications because it was specifically designed for precise, secure, realtime measurement of location, distance and direction while concurrently supporting twoway communication. It is 50x faster than GPS, with updates up to 1000x per second, which is 3000x faster than a standard BLE beacon! It is also extremely reliable, with high immunity to interference, including reflected signals or multipath effects common indoors.

UWB technology is being incorporated into leading smartphones and many other devices and is poised for mass adoption worldwide, with a potential market of billions of units. It is already being used in more than 40 different industries, in consumer and business systems for healthcare, factory automation, automotive and others. But its greatest potential is in new generations of micro-location-based applications. Just as Wi-Fi and Bluetooth enable many applications that extend far beyond the original uses of those technologies, UWB will become ubiquitous

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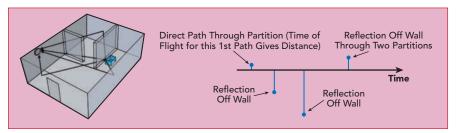


Fig. 1 UWB is resistant to multipath because it uses ToF to calculate distance.

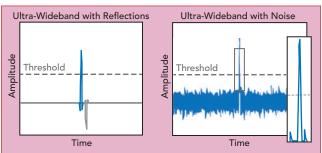


Fig. 2 UWB pulses are not affected by reflections or noise.

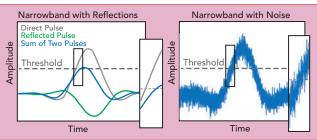
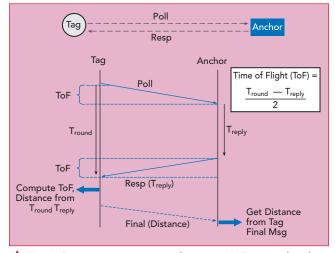


Fig. 3 Impact of reflections and noise on measuring ToA with narrowband signals.



▲ Fig. 4 Secure two-way ranging between UWB tag and anchor.

and enable applications that haven't yet been conceived.

HOW UWB WORKS

UWB has unique characteristics that enable it to determine distance and location more accurately than other technologies, even in the presence of noise and multipath interference. One of UWB's key strengths is

using time-of-flight (ToF) information to calculate distance and direction. Using timestamped signals, UWB calculates the time for signals to travel between devices, then multiplies that time by the signal speed (i.e., the speed of light) to obtain the distance between them.

In contrast, Wi-Fi and BLE rely primarily on received signal indicastrength tor (RSSI) method. This measures the strength of ceived signals to determine the distance from a transmitter, since a radio signal's strength varies according to the inverse square the distance from the transmitter in free space. A key problem using the RSSI method is signal strength being affected by other factors, such as whether the signal is passing through walls or reflected by objects. A weak

signal strength would lead the receiver to estimate the transmitting object is farther away-when, in fact, the signal has been attenuated only because it passed through a wall. Technologies that rely on RSSI can yield misleading distance and location measurements in indoor environments.

Figure 1 shows the advantage of

using ToF indoors to calculate distance. In the diagram, a UWB signal transmitted by the blue device on the right reaches the gray device on the left via several different paths. One path reaches the gray device directly through an intervening wall; the other paths involve reflections and are longer. Because the direct path is the shortest, it reaches the gray device first and is used to calculate the ToF. The multipath signals can be ignored because the system relies on ToF to determine distance. This method works even if the direct signal is weaker than the reflected signals. Note that UWB only requires a single measurement to determine position accurately and reliably, while other RF technologies require multiple samples with filtering to determine location.

Because radio signals travel at the speed of light, extremely accurate measurement of ToF is necessary to determine distance within centimeters. The UWB signal is designed to help achieve this goal. Unlike other radio technologies, UWB does not encode information using amplitude or frequency modulation. Instead, UWB communicates information with short sequences of brief pulses using binary phase-shift keying and/ or burst position modulation to encode the data. UWB signals also use much greater bandwidth than narrowband technologies, typically 500 MHz. As a result, each pulse is extremely short—only 2 ns—due to the inverse relationship between time and bandwidth. These pulses have much faster rise and fall times than narrowband signals, making it possible to precisely measure the time of arrival (ToA) of the signal. This also helps UWB signals maintain their integrity and structure in the presence of noise and multipath. As shown in Figure 2, because the UWB pulse is so short, it is separate from and unaffected by a reflected signal. Even under noisy conditions, the time is barely affected.

The ToF-based approach has also been tried with narrowband radio technologies; however, as shown in Figure 3, a narrowband signal is very sensitive to multipath. A reflected signal may combine destructively with the direct signal to cause errors at the receiver. De-



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structive interference shifts the time when the signal crosses the threshold, which is used to measure the signal's ToA, resulting in poor accuracy. Noise also adds uncertainty to the ToA of the signal.

Knowing where people and assets are in real-time can also provide new methods of security. If physical presence cannot be faked, a person's location can be used as a security credential, restricting access to areas and protecting physical assets, data and communications. Effectively, secure location information can be used to create virtual walls and boundaries for wireless networks. For example, because UWB uses ToF instead of RSSI to determine distance, it guards against relay attacks. In a relay attack, a malicious actor picks up a signal and amplifies it to trick the receiver into concluding a transmitting device is closer than it really is.

UWB TOPOLOGIES

UWB technology can be implemented in different ways to address a wide range of needs. Depending on the implementation, UWB can be used to measure distance, 2D or 3D location and direction. The principal topologies are:

- Two-way ranging (TWR)
- Time difference of arrival (TDoA)
- Reverse TDoA
- of arrival (PDoA). The concepts "anchor" and "tag" are important to understand distance and location measurement with UWB. An anchor is generally a fixed

UWB device with a known location. A tag generally refers to a mobile UWB device. An anchor

and tag exchange information to establish the distance between them.

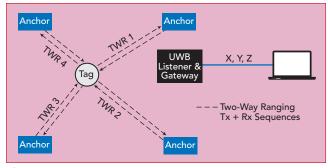
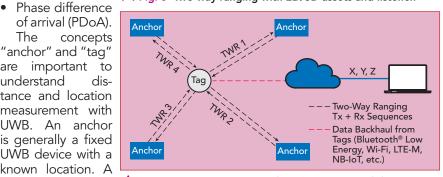


Fig. 5 Two-way ranging with 2D/3D assets and listener.



▲ Fig. 6 Two-way ranging with 2D/3D assets and data tag backhaul.

The exact location of a tag can be determined by communicating with multiple anchors. Some devices can act as either an anchor or tag. For example, when two mobile phones use UWB to calculate the distance between them, they may switch roles during the process, alternating between tag and anchor.

TWR — This method calculates the distance between a tag and an anchor by determining the time it takes for the UWB RF signals to pass between them (ToF), then multiplying that time by the speed of light. A keyless car entry system is an application that uses TWR for secure and accurate distance determination (see Figure 4). As shown in the figure, the tag initiates TWR by sending a poll message with the known address of an anchor. The anchor records the time it receives the poll message and sends a response. When the tag receives the response, it calculates the signal ToF based on the signal round-trip time (T_{round}) and the time for the anchor to process and reply to the initial poll message (T_{reply}). The distance is calculated by multiplying the ToF by the speed of light. The tag can then pass the calculated distance to the anchor in a final message, if required.

With multiple anchors, TWR can determine the absolute position of mobile devices or other tags. By





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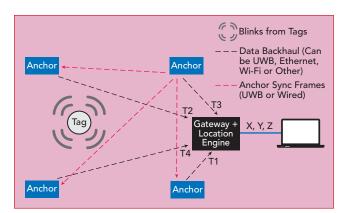


Fig. 7 Determining location with TDoA.

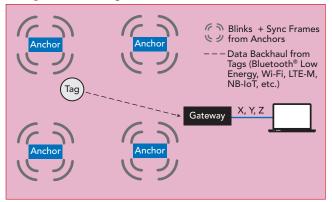


Fig. 8 Reverse TDoA.

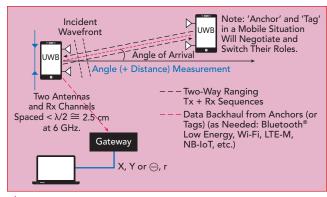


Fig. 9 Using PDoA to calculate direction and distance.

determining the distance to three or more anchors in known locations, the device can estimate its location with great accuracy. It can then communicate the distance via UWB or other wireless technologies to location-based applications or gateways (see *Figures 5* and *6*). The disadvantage of using TWR for location measurement in this way is the tag does frequent communication, which increases its power consumption and limits scalability.

TDoA — This method is extremely scalable for determining the location of tags within a venue. Because tags only transmit once during the process, they use very little power and have a very long battery life. Multiple anchors are deployed in fixed and known locations and are tightly time synchronized. When a mobile device sends a "beacon" or "blink" signal, each anchor that

receives the signal "time stamps" its arrival based on the common synchronized time base. The time-stamps from multiple anchors are then forwarded to a central location engine, which runs multilateration algorithms to determine the device's location based on the differences in arrival times at each anchor (see *Figure 7*). The result is a 2D or 3D position for the mobile device.

RTDoA — It is also possible to implement a reverse TDoA system, which works a bit like GPS. The anchors transmit synchronized blinks with fixed or known offsets to avoid collisions, and the mobile devices use TDoA and multilateration algorithms to compute their respective locations (see *Figure 8*).

PDoA — This method enables two devices to calculate their relative positions without needing any other infrastructure by using a combination of distance and directional information. This is important for peer-to-peer applications or to reduce the infrastructure to be deployed. For PDoA, one of the devices must have at least two antennas (see *Figure 9*). When this device receives a signal from the other de-



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vice, it measures the difference in the phase of the arriving signal at each antenna. Based on this difference, it calculates the angle from

which the incoming signal arrived. of the transmitting device.

The receiving device now knows both the direction and the distance

TABLE 1							
UWB CHANNELS AND GEOGRAPHIC USE							
Channel	Carrier Frequency (MHz)	Bandwidth (MHz)	Region				
0	499.2	499.2	Proprietary				
1	3494.4	499.2	US, EU				
2	3993.6	499.2	US, EU, Japan, Korea				
3	4492.8	499.2	US, EU, Japan, Korea				
4	3993.6	1331.2	US, EU				
5	6489.6	499.2	US, EU, China				
6	6988.8	499.2	US, EU, China				
7	6489.6	1081.6	US				
8	7488	499.2	US, EU, Korea, China				
9	7987.2	499.2	US, EU, Japan, Korea, China				
10	8486.4	499.2	US, EU, Japan, Korea, China				
11	7987.2	1331.2	US, Japan, Korea				
12	8985.6	499.2	US, Japan, Korea				
13	9484.6	499.2	US, Japan, Korea				
14	9984	499.2	US, Japan, Korea				
15	9484.8	1354.97	US, Japan, Korea				



For simplicity, Figures 5 through 9 only show one tag; however, UWB applications can support many tags.

UWB FREQUENCIES

UWB operates in regulated unlicensed spectrum, so anyone can implement UWB communications without a telecommunications license if the system operates within the regulated frequency and power range. The Federal Communication Commission (FCC) defines the UWB frequency range from 3.1 to 10.6 GHz and UWB systems as those operating with 1) an absolute bandwidth larger than 500 MHz at a maximum power density at a central frequency (f_c) above 2.5 GHz or 2) a fractional bandwidth greater than 0.2 with f_c lower than 2.5 GHz. UWB spectrum is divided into channels; not all channels are used in all regions (see Table 1).

Although UWB's large bandwidth is very useful, it means the frequencies used overlap with those of other communications technologies (see Figure 10). The FCC and other regulatory organizations therefore limit the power of UWB transmissions to avoid interference (see Table 2). The FCC limits the radiated power to -41.3 dBm from 3.1 to 10.6 GHz, with tighter restrictions in other frequency ranges.

THE FUTURE OF UWB

UWB is on the brink of mass adoption, now used in more than 40 market verticals for a range of applications, including:

- Secure keyless entry to cars
- Locating essential supplies in hospitals
- Improving operational efficiencies and safety in factories
- Controlling smart devices in homes, based on user's location.

Integrating UWB into smartphones is a key step to the use of UWB in our daily lives. UWB-en-

TABLE 2					
UWB EIRP LIMITS					
Frequency (MHz)	EIRP (dBm)				
960-1610	-75.3				
1610-1990	-53.3				
1990-3100	-51.3				
3100-10600	-41.3				
Above 10600	-51.3				



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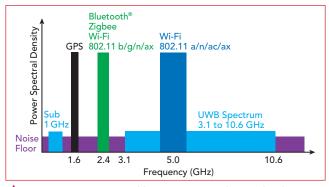


Fig. 10 Spectrum used by common wireless technologies.

abled smartphones will trigger the development of a broad ecosystem of new devices and applications that cannot be implemented with other technologies. UWB is a potentially revolutionary technology that will ultimately become ubiquitous—impossible to imagine today all the ways that it might be used in the future.

However, it typically takes time to realize the full potential of a new technology and have it adopted into mainstream use. It is therefore difficult to predict the future of UWB adoption. Yet history gives us some hints about its possible trajectory. For example, Wi-Fi started as a proprietary wireless communications solution for cash registers in the early 1990s. Apple's endorsement of Wi-Fi in 1999 helped spur its rapid adoption, with development of a rich ecosystem of devices and a network effect that led to annual shipments of billions of units.

Interoperability is key to mass adoption, as is the development of full-featured software stacks and hardware solutions developers can use as application building blocks. Several industry consortia are working on interoperability, UWB use cases and regulation. Participants include a wide range of companies, from semiconductor suppliers to device manufacturers, carmakers, test equipment vendors and app developers. The FiRa ConsortiumTM is developing use cases across many industries, including hands-free access control, indoor location and navigation, as well as peer-to-peer applications. The consortium's mission includes developing test specifications, certification programs and events to ensure interoperability between UWB products. The Car Connectivity Consortium (CCC) is working on smartphone-to-car connectivity solutions. CCC is developing the Digital Key, a new open standard that enables smart devices like smartphones and smartwatches to act as vehicle keys. The UWB Alliance is working with global regulation bodies and organizations to ensure a favorable regulatory and spectrum landscape to maximize UWB's market growth.

CONCLUSION

UWB is uniquely capable of calculating location, distance and direction with unprecedented accuracy, indoors and outdoors, securely and in real-time. These capabilities will lead to a new wave of micro-location-based applications delivering new experiences and capabilities, no doubt many that weren't previously possible.

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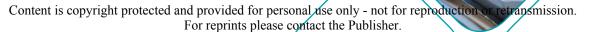
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The Path to Lowest Phase Noise: A Fully Integrated Translation Loop

Erkan Acar Analog Devices, Wilmington, Mass.

We are experiencing explosive growth in demand for bandwidth that pushes carrier frequencies to multiple decades of gigahertz. At these extremely high frequencies, consumers can enjoy wider bandwidth without fear of overcrowding the spectrum. However, as the frequencies increase, the instrumentation solutions targeting these devices and frequencies become extremely complex. This stems from the need for an order of magnitude better performance in instrumentation to prevent impairing the device under test. This article discusses several methods for low phase noise signal generation, describing the advantages and disadvantages of each and introducing the translation loop device, which takes the best of all frequency generation methods without their complexities to achieve ultra-low phase noise signal generation.

hase-locked loop (PLL) circuits are common in many frequency generation devices (see *Figure 1*). The PLL ensures the waveforms and signals created within a device are phase aligned or locked to a reference signal. The output of the voltage-controlled oscillator (VCO) is divided using an N counter and compared to a reference signal using the phase/frequency detector (PFD). The PLL is a simple circuit that has been extensively studied and the subject of numerous textbooks. We will use some of the well-known basics to establish what it takes to drastically reduce the phase noise at the output. Phase noise

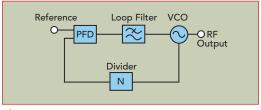


Fig. 1 PLL block diagram.

from each building block contribute to the overall phase noise of the PLL circuit. The phase noise associated with each block can be modeled, and the overall phase noise of the PLL precisely predicted, both through simulation and analytical calculation.

The PFD compares the reference signal to the divided output frequency. It produces an error signal that is fed to a charge pump circuit to create a control voltage, steering the VCO until the output phase of the device matches the reference phase. The data sheets for most frequency generation devices with integrated PFD circuits provide a figure of merit (FOM). Using the FOM, the in-band phase noise can be calculated as:

$$L_{OUT} = FOM + 10 \log f_{PFD} + 20 \log N$$
 (1)

where f_{PFD} is the PFD frequency and N the value of the output frequency divider. The output frequency is a multiplication of the

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Protocols













Applications

- Home and building automation
- Smart metering
- Industrial monitoring and control
- Smart parking
- Wireless alarm systems
- Asset tracking
- Remote keyless entry



ApplicationNote

 f_{PFD} and N divider value. For a given output frequency, as the f_{PFD} increases by a factor, N decreases by the same factor. This results in lower overall output phase noise because any reduction in N reduces the phase noise by twice the rate of the increase from the f_{PFD} term. The greater the PFD frequency, the lower the close-in phase noise, which can be exploited to reduce the overall phase noise.

The loop filter follows the PFD and smooths the error signal from the PFD device that steers the VCO. It is designed using several parameters of the system: the charge pump current, VCO sensitivity and PFD frequency. One of the less emphasized functions of the loop filter is that it determines the bandwidth of the negative feedback control loop. The reference signal will influence the output signal's phase

noise within the control bandwidth of the loop filter. Beyond this cutoff frequency, the overall phase noise performance will be defined by the VCO characteristics. This fact will be used to optimize the overall phase noise of the system.

The VCO creates the output frequency based on the control voltage applied at its input. The VCO output frequency is updated by the control loop until it is phase-locked to the reference signal's phase. The VCO directly influences the overall phase noise of the system. In general, as the quality factor of the VCO increases, its phase noise reduces.² However, a higher quality factor usually requires components that limit VCO tunability. VCOs tuned for narrow frequency operation typically have the best phase noise performance.

FREQUENCY GENERATION

Instrumentation applications typically strive for the best performance, i.e., both low phase noise and spurious levels. Various oscillator topologies can be used to generate signals, which yield varying levels of quality. These include:

Fixed Frequency Oscillators

Fixed frequency oscillators are signal generation devices that have excellent phase noise performance. These devices typically have very high-quality factors, enabling superior close-in phase noise performance. They operate at a predetermined frequency, largely defined by the geometry and the construction of the device, with some tunability to enable phase-locking to a reference source. Oven controlled crystal oscillators (OCXOs), temperature compensated crystal oscillators (TCXOs) and voltage-controlled surface acoustic wave (SAW) oscillators are some examples of these devices. One key disadvantage of fixed frequency oscillators is their limited frequency coverage. While they may be suitable for devices operating at a fixed set of frequencies or multiples of those frequencies, most instrumentation devices require variable frequency coverage.

Using a direct digital synthesis (DDS) or digital-to-analog converter (DAC) is one solution to this prob-



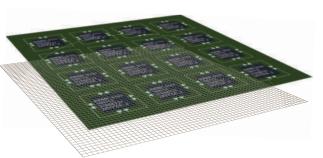


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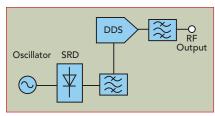
ApplicationNote

lem (see *Figure 2*). The fixed frequency signal can be used to drive the sampling clock of a DDS device, with the oscillator's frequency multiplied as needed through a frequency multiplier or a step recovery diode and filtered before it is applied to the DDS. The DDS can create any arbitrary frequency up to half the sampling frequency in the first Nyquist zone of operation. Some modern DACs can even operate

comfortably in the second Nyquist zone.

Figure 3 shows an example of the output spectrum and phase noise of the Analog Devices AD9164 driven by a low phase noise dielectric resonator oscillator at 6 GHz. The phase noise plot shows incredibly low output phase noise, with output spectrum spurs less than -70 dBc.

The spectral purity of the multiplied sampling clock has a direct in-



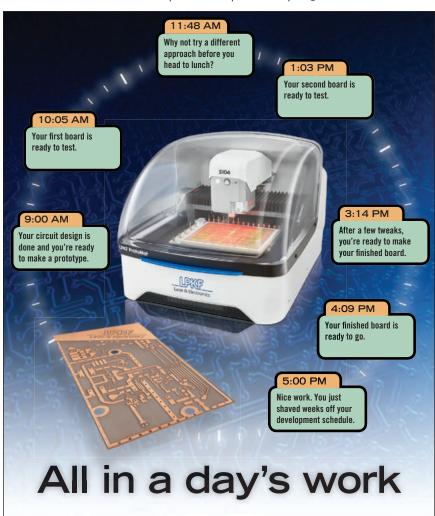
▲ Fig. 2 Variable frequency generation using a fixed source.

fluence at the output of the device. Once the signal is multiplied, many harmonics will be present at the output. Typically, the spurs at the sampling clock will appear at the output at similar levels. The desired signal then needs to be filtered to achieve very low spurious levels at the output of the DDS. For large multiplication factors, the filters may need to be extremely sharp, which can require significant area.

The phase noise of the multiplied signal increases as the multiplication factor increases. For example, every time the signal frequency is doubled, the phase noise increases by 6 dB. Based on the starting phase noise profile and multiplication factor, the noise floor of the far-out phase noise can increase significantly, making the overall solution less appealing. This is a well-known dilemma, where leveraging the close-in phase noise of a single frequency, high-quality factor device comes with a far-out phase noise floor penalty. As an example, SAW devices have excellent closein phase noise performance, with carrier frequencies around 1 GHz. Using one for a mmWave application operating above 40 GHz would require multiplication as high as 40, which could result in greater than a 32 dB increase in the phase noise floor, which could make the solution less appealing.

Wideband PLL Devices

Wideband synthesizers solve many of the challenges associated with single frequency devices. These use multiple VCO cores that are further divided into multiple overlapping bands. This architecture enables each core and band to be designed with a high-quality factor. This significantly improves the overall performance of the device compared to architectures using a single core. One key advantage



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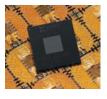


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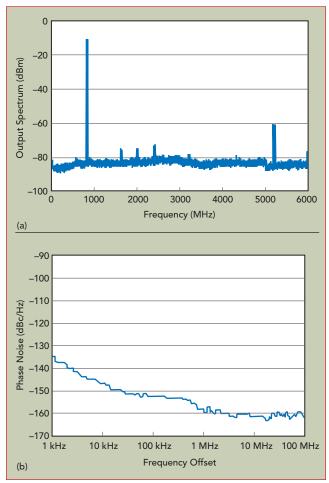


Fig. 3 Output spectrum (a) and phase noise (b) of the AD9164 at 800 MHz, using a fixed frequency oscillator as the sampling clock.

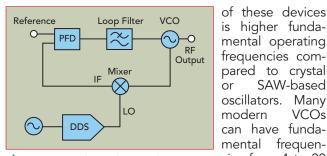


Fig. 4 Translation loop architecture.

cies from 4 to 20 GHz or higher. This makes their far-out phase noise in mmWave applications much more appealing. For example, a device operating at a 10 GHz fundamental frequency only requires multiplication by 4x to extend the frequency to 40 GHz, which translates to a phase noise floor increase of 12 dB, compared to a 32 dB increase using a crystal

One challenge associated with multicore and multiband devices is finding the optimum band to synthesize the target frequency. This could involve creating lookup tables to identify the correct band. Devices equipped with autocalibration features make this process much easier and robust to temperature and process variations. This vastly simplifies the overall operation of the device,

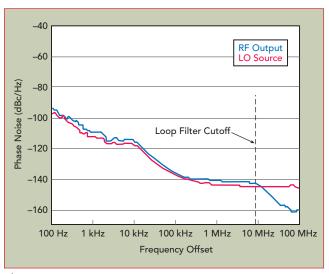
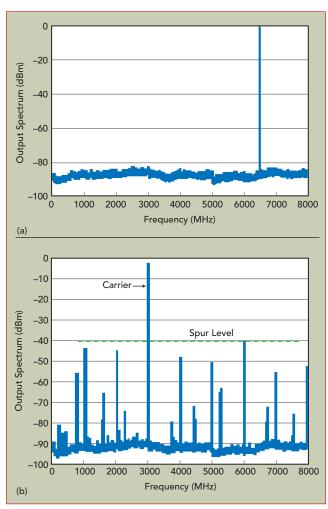


Fig. 5 Phase noise profile of a translation loop device.



🖊 Fig. 6 Translation loop output spectrum at 6.5 GHz (a) and LO input spectrum at 3 GHz (b).

where frequency changes can simply be programmed into the registers of the device and the optimum band automatically determined. Another challenge with this option is that the close-in phase noise of these devices is typically much higher compared to single frequency devices. Even with the lower overall phase noise floor,

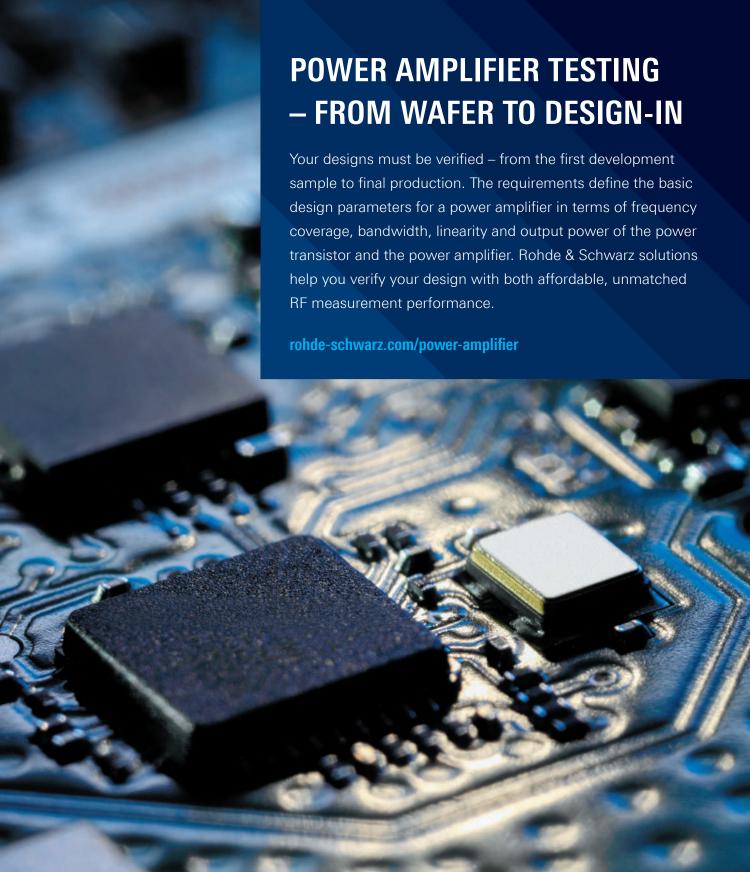
SAW-based

Many

VCOs

frequen-

oscillator.



ROHDE&SCHWARZ

ApplicationNote

the higher close-in phase noise can result in higher overall integrated noise, limiting their use in applications that demand lower integrated phase noise.

Translation Loop

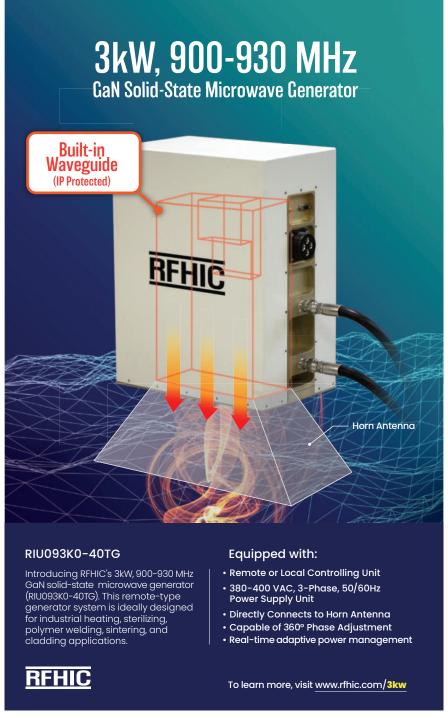
The translation loop takes the best of all these frequency generation methods without their disadvantages. To see why, recall that single frequency devices such as

OCXOs, SAWs and crystals with high-quality factors have the best close-in phase noise. These single frequency devices usually have low fundamental frequencies, making the far-out phase noise less appealing when they are multiplied to mmWave frequencies. An ideal solution would take advantage of the close-in performance of these devices without the far-out phase noise penalty. DDS or DAC devices

can be used to generate variable frequencies using fixed frequency devices. These also suffer from the large multiplication factors needed for mmWave frequencies and filtering to reject subharmonics and other spurs. Tolerating these shortcomings can enable a desirable solution. Wideband synthesizers can have very high fundamental frequencies with excellent far-out phase noise performance. However, these devices do not really have high-quality factors, making the close-in phase noise relatively poor compared to single frequency devices. Leveraging the far-out phase noise without the degraded close-in phase noise would be necessary.

This brings us to the translation loop device (see Figure 4). Instead of dividing the output frequency by a large divider value, a frequency mixer is used to shift the output signal to an intermediate frequency (IF) that matches the reference signal's frequency. This effectively reduces the divider value to 1, eliminating the noise contribution originating from the typically large divider values used in traditional PLL devices. This also imposes the phase noise profile of the local oscillator (LO) on the control loop. A single frequency device with excellent close-in performance and a DDS can be used to

create this LO signal. The loop filter bandwidth is a critical design parameter for the translation loop device. As discussed, the loop filter determines the overall bandwidth of the control loop, i.e., it defines how far the reference and LO signal influence the output phase noise. We can choose a large loop filter bandwidth for the translation loop since the close-in phase noise can be extremely low. Figure **5** shows the phase noise profile of a translation loop device and its LO input. The figure shows the LO phase noise, which is extremely low close-in but has a high far-out noise floor. However, the phase noise of the RF output only tracks the LO phase noise up to the loop filter bandwidth. After this frequency offset, the far-out phase noise is defined by the VCO, which is extremely low. By selecting a large loop bandwidth, the translation loop device leverages the desirable





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ApplicationNote

close-in performance of a single frequency device using a DDS as an LO and the far-out phase noise of a wideband VCO. This approach breaks the well-known dilemma about which phase noise region to optimize, resulting in extremely low output phase noise.

The superior phase noise performance of the translation loop makes it very useful in many mmWave instrumentation applications. In ad-

dition to low phase noise performance, instrumentation is also expected to suppress spurious signals to extremely low levels. This can be tremendously challenging with translation loop devices because of several strong signals at different frequencies. In many cases, it is challenging to prevent feedthrough of the LO and intermediate frequency (IF) signals to the output. Further, many intermodulation

products of the IF, LO and RF can be created at the output, and these spurious signals can cause the overall instrumentation solution to have poor spurious performance.

An example of a translation loop device which addresses these challenges, the Analog Devices ADF4401A eliminates all the feedthrough paths that could exist in a discrete implementation with built-in shielding and design practices minimizing feedthrough. The result is spur rejection of -90 dBc, which rivals yttrium iron garnet sphere-based oscillators.

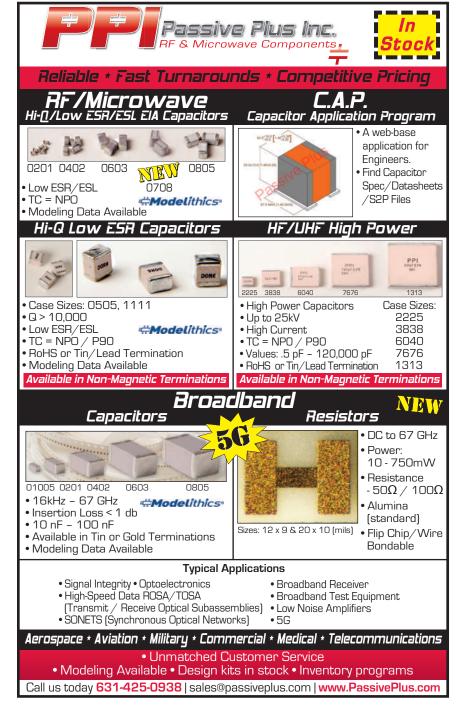
The output of the ADF4401A can have low spur levels even if the inputs to the system are less than ideal. Figure 6a shows the output spectrum with an LO input that contains many spurs around -40 dBc (see **Figure 6b**). Typically, this type of an LO signal is not usable in instrumentation because of the extensive amount of filtering needed. However, the ADF4401A can accept this LO input without requiring additional filtering, producing the output shown in Figure 6a. The device has an autocalibration engine to identify the optimum VCO band for a given target frequency. In the calibration mode, the device searches for the correct band under actual temperature and process conditions, making frequency tuning streamless.

SUMMARY

Instrumentation solutions require very low phase noise carrier signals with extremely low spurious levels to meet the demands of mmWave systems. While various methods are used to synthesize these signals, all have significant trade-offs, making a solution complex. The translation loop architecture leverages the advantages of several frequency generation options—without the disadvantages—to achieve ultra-low phase noise and spurious signals without complex filtering.

References

- I. Collins, "Phase-Locked Loop (PLL) Fundamentals," Analog Dialogue, Vol. 52, No. 3, July 2018.
- 2. D. B. Leeson, "A Simple Model of Feedback Oscillator Noise Spectrum," *Proceedings of the IEEE*, Vol. 54, No. 2, February 1966.







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Low-Cost, Low-Power 5G Infrastructure Transceiver Covers All Sub-7 GHz Bands

SiTune San Jose, Calif.

ith the influx of new technologies and applications requiring higher data rates and better service coverage, bandwidth and antenna array expansion are key to fast and reliable communication from high density 5G networks. The attendant infrastructure scaling, however, must be managed to minimize the growth of energy consumption as the number of data packets expands.

An integral part of the base station radio, transceivers up-convert and transfer the physical layer signal from the baseband signal processor to the RF or mmWave power amplifiers (PAs) and antennas. They also down-convert from the RF or mmWave ana-



▲ Fig. 1 HIC improves the performance of low-power mixedsignal ICs.

log signal and transfer it back to the base-band processor. With frequencies and band-width increasing, up- and down-conversion face challenges to ensure signal quality while minimizing power consumption. Analog circuits do not follow Moore's law, they are not modular, and every circuit must be customized to meet unique requirements. To meet the tighter 5G New Radio (NR) specifications for data rates, noise and linearity, traditional analog circuit designs will consume more energy and board area.

HARDWARE INTELLIGENT CIRCUITS

To address these 5G challenges, SiTune developed the recently announced Snow-WingsTM, a multi-standard, scalable RF transceiver chipset using direct RF sampling, which provides significant advantages in cost and power consumption. The transceiver's reduced power consumption is achieved using SiTune's Hardware Intelligent Circuits (HICTM) technology, which enables the development of energy efficient radio units (RUs) and simplifies the radio access network (RAN) architecture. SnowWings provides a 70 percent reduction in power consumption compared to other devices in the market.

SiTune's HIC is a patented design concept based on combining hardware and software to create calibration and digital correction techniques that optimize and improve the



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These synthesizers are designed and manufactured for standard test instrumentation, communication, and radar systems applications as a local oscillator. There are two main types of SOTs, the first being the high-speed modules, which have exceptional high hopping speeds ranging from 3 μS to 500 nS. The next being the low phase noise models, which have superior low phase noise performance, a connection cable set, and is supported by an optional evaluation

The synthesizers can operate on both internal and external reference sources, the phase noise will be dependent on the quality of the reference source, if an external source is being applied. The various models can range anywhere from 0.1 up to 20 GHz and multiple output power levels from as low as-20 dBm up to +16 dBm. All SOTs come with a GUI (Graphic User Interface) for initial system set and rapid system development.



ProductFeature

performance of custom, low-power analog circuits (see Figure 1). Rather than the traditional tradeoffs of increasing circuit area and power consumption to reduce noise and increase linearity, HIC technology builds on low-power circuit design and optimizes performance through "intelligent" modifications. This is done with enhanced mixed-signal IC design where the digital signal provides feedback, closing the loop to improve the performance of the

analog circuit.

Based on direct RF sampling, the internal architecture of SnowWings (see Figure 2) uses high precision data converters and low noise amplifiers to ensure the received signal quality at the baseband and the transmit signal at the PA surpass the signal quality required for 5G NR. Using direct RF sampling avoids I/Q imbalance and local oscillator leakage. By disaggregating the digital baseband from the analog RF and

IF, SnowWings handles the digital predistortion (DPD) for the PA, crest factor reduction and much of the critical digital signal processing operations. This capability enables flexible and scalable RU designs, where the RU can adapt to digital signal processing changes, split 7x modifications and expansion of the antenna arrays. Also, SnowWings is flexible in choice of baseband, since it supports a standardized digital interface (JESD204B/C) for baseband IC processor or FPGA implementations, while achieving a low-power, high performance hardware design.

SnowWings supports any licensed or unlicensed band from 600 MHz to 7.2 GHz, including LTE, 5G NR and CBRS. To achieve hardware design flexibility, the innovative concept of multi-band convergence was implemented in the design, meaning a single pluggable IC can cover all sub-7 GHz bands with an additional low noise amplifier stage at the uplink and preamplifiers at the downlink. This capability supports dynamic spectrum sharing between LTE and 5G NR solutions using the non-standalone imple-

mentation.

SUPPORTING O-RAN

The 5G open RAN (O-RAN) architecture vision is about disaggregating hardware and software to promote

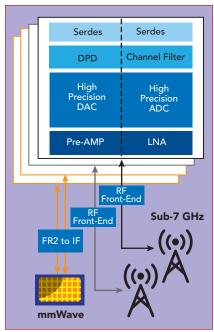


Fig. 2 SnowWings transceiver block diagram, showing the interface to the RF front-end.



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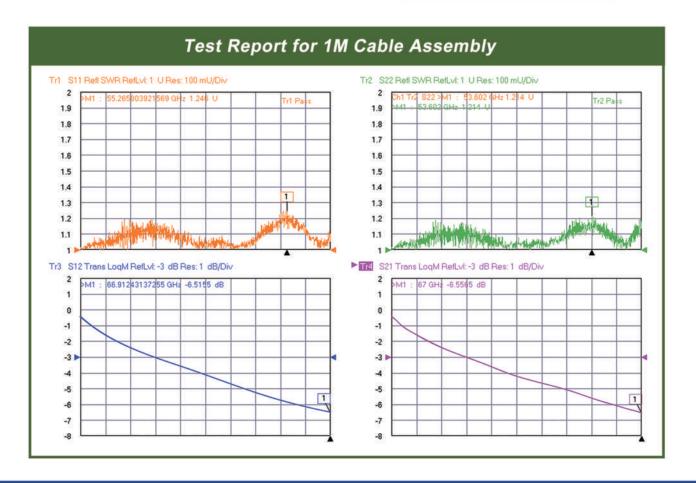
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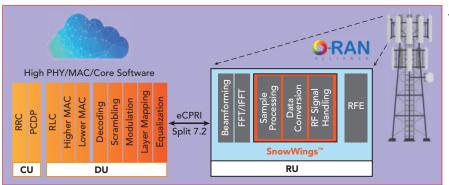


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Fig. 3 O-RAN architecture.

open interfaces and interoperability. This involves virtualization of the distributed unit (DU) and central unit of the RAN to provide operators with faster network upgrades through remote software updates. Another important objective of the O-RAN concept is enabling network operators and private enterprises to select the best separate hardware components to build a network with the highest performance and lowest cost.

With the restructuring of the RAN architecture, partitioning O-RAN hardware components in such a way that hardware programmability and scalability is realized becomes particularly important. As shown in Figure 3, the transceiver architecture plays a key role in the RU, as the frequency bands, bandwidth, number of antenna arrays and other characteristics change depending on the application and usage. For example, for mMIMO, macro or small cell scenarios, the RU specifications vary widely and the functionality splits will change between the hardware RU and virtualized DU. The functional partitioning of Snow-Wings with its low-power enables a truly scalable RU design. Using multiple SnowWings ICs and stacking multiple programmable L1/low PHY solutions enables various mMIMO implementations without redefining the entire RU architecture. Providing mmWave and sub-7 GHz convergence in indoor and outdoor access points with a single transceiver provides flexibility.

SnowWings offers the lowest power consumption with design and architectural flexibility through patented innovations in RF, data converters, mixed-mode circuit design, digital correction techniques and algorithms for communication systems. Its 70 percent reduction in power consumption compared to other devices in the market, achieved through SiTune's HIC technology, leads to lower cost RUs, reducing the total cost of ownership for enterprise and telecom product manufacturers and operators.

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TechBriefs



ub-6 GHz base station power amplifiers (PAs) use one of two competing technologies: Si LDMOS or GaN. As the frequency and power efficiency requirements for 5G push LDMOS technology to its limits, GaN is slated to surpass LDMOS as the dominant choice for future base station PAs. The higher power density, better operating efficiency, smaller size, faster switching speed and higher frequency coverage will make GaN the preferred PA technology for sub-6 GHz 5G.

GaN's capability and performance improvements bring new characterization and test requirements to ensure specification com-

High-Power Production Test for Base Station Power Transistors

pliance and reliability. To meet these requirements, Roos Instruments has added the RI8589 High Power Supply/Pulser to its modular Cassini ATE platform. Designed for LDMOS and GaN testing, the RI8589 is an all-in-one solution for power device characterization. It provides multiple high voltage supplies from -60 to +180 V, a pulsed supply capable of delivering 1 kW with microsecond measurement capability and precision microamp current measurement. Other features of the RI8589 include dynamic on-resistance (Rdson) and pulse profile measurements, temperature characterization, switching between high voltage and high current measurements without re-cabling and built-in safety interlocks.

The RI8589 High Power Supply/ Pulser is an add-on test capability to the modular Cassini ATE platform, enabling users to customize ATE measurements to specific device needs, with the capability to adapt to future requirements. Combined with high-power microwave instruments and configurable device interfacing, Cassini ATE is an all-in-one solution for power device characterization and production test.

Roos Instruments, Inc. Santa Clara, Calif. roos.com



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The MRFXF5716 uniquely offers a DC bias tap that will carry 400 mA without saturating the magnetic core, a design element to improve the performance of a push-pull amplifier. The high current handling enables an amplifier to deliver higher output power with fewer distortion products, which has been demonstrated with a 12 V push-pull amplifier measuring 2 to 3 dB improved modulation error ratio. The balun will handle 2 W RF output power.

The MRFXF5716 has a pin to provide current to both legs of the RF amplifier output, eliminating the cost of RF bias choke components. This feature also simplifies the RF circuit layout and reduces the foot-

print on the printed circuit board, yielding additional cost savings. The MRFXF5716 operates from -40°C to +100°C and is assembled in a miniature surface-mount package measuring 0.150 in. x 0.150 in.

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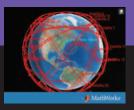


New Tool for Satellite Communications Design

The Satellite Communications Toolbox in MATLAB provides standard-based tools for designing, simulating and verifying SATCOM systems and links. The toolbox enables you to model and visualize satellite orbits, perform link analysis and access calculations.

MathWorks

https://bit.ly/3dTGjan



Let's Ride the Wave with PRÂNA!



Don't miss the boat by staying connected to all PRÂNA news, including a behind the scenes photoshoot video, and surf on the amplifiers wave on their LinkedIn page!

PRÂNA

www.linkedin.com/feed/update/urn :li:activity:6785576752191156225/





5G Tool Kit Improves Test Accuracy

This blog reviews Rosenberger 2.4 and 1.85 mm tool kits for 5G mmWave component and subsystem testing with an emphasis on precision measurements.

RFMW

https://rfmwblog.com/2021/04/27/ 5g-tool-kit-application-brief/



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AMP2043P-8KW, **1.0-2.0 GHz 8KW Pulse**Content is copyright protected and provided for personal use only - not for reproduction or retransmission.

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www.richardsonrfpd.com/ rfdesign





Equalizing Slope Gain in RF & Microwave Design

Understand RF wideband microwave gain slope, installation and reliability for your next military or space RF application in this Smiths Interconnect blog post.

Smiths Interconnect https://bit.ly/3xk8bfE





Samtec offers RF interconnect solutions to 110 GHz. Samtec RF products are available as quickturn, off-the-shelf assemblies or can be customized to further support next-generation demands.

samtec.com/RFcatalog

New RF Catalog





Achieve Near Metrology Grade Performance for Less

Precision adapters from Southwest Microwave are economical solutions that deliver near metrology grade VSWR and insertion loss performance for applications not requiring phase matching.

Southwest Microwave https://youtu.be/uCPibF21UXY







VITA RF Product Portfolio, **Enabling an Open VPX** World

The VITA 67.3 specification draws on the solutions provided in 67.1 and 67.2, but is unique as it doesn't define the locations of the ports like its predecessors.

ps://bit.ly/2SHkC56





GaN Solutions: Small Packages for Big Radar Challenges

Radar designers can use GaN to overcome AESA system challenges as tech in the defense continues to grow, learn more in Wolfspeed's Knowledge Center's article.



Microwave / RF Ceramic Capacitor

DLC70 Series High Q,NPO, RF/Microwave MLCC

Product Features

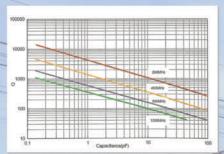
- High Q
- Zero TCC
- Low ESR/ESL
- Low Noise
- Ultra-Stable Performance
- Extended WVDC available

SIZE:0402,0603,0505,0805, 0710,1111,2225,3838 for RF/Microwave: 6040,7575,130130 for High RF Power

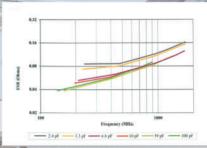
Typical Circuit Application:

UHF/Microwave RF Power Amplifiers, Mixers, Oscillators, Low Noise Amplifiers, Filter Networks, Timing Circuits and Delay Lines.

Stock available



DLC70A(0505) Q Value and Capacitance Curve



DLC70P(0603) Equivalent Series Resistances (ESRs)

3 lic?

Dalicap Tech. is a professional enterprise specializing in R&D, manufacturing and sales of multi-layer ceramio capacitors (MLCC). Dalicap is also a leading supplier of Hi-Q, ultra-low ESR RF/Microwave MLCC, applied especially on the fields of MRI, semiconductor device, industrial laser equipment, testing and analyzing instruments, balise and 4G/5G PA etc.

Dalicap is committed to providing high-performance, high-reliability products to customers. The R&D and engineering teams have extensive experience to quickly support and response to customized request. The company has an unique RF lab, by RF simulation and individual RF testing method to guarantee product realization.

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COLORADO CONVENTION CENTER
Denver, Colorado



IEEE MICROWAVE THEORY & TECHNIQUES

IMS2022 is the centerpiece of Microwave Week 2022, which includes the

RFIC Symposium (www.rfic-ieee.org) and the ARFTG Microwave Measurement Conference (www.arftg.org).

The Peaks of Microwaves

Join us as we explore the new Peaks of Microwaves including:

- Radar, Phased Arrays, OTA test: the triumvirate of modern microwave systems
- Microwaves for Tiny AI and IoT
- Hardware for Intelligent Mobility, Automotive, and IIoT applications
- Microwaves and satellites for Space 2.0
- 5G/6G Hardware: from components to system-on-chip and RF to THz
- Quantum RF Engineering
- Evolving RF/EM design strategies

Microwave Week provides a wide variety of technical and social activities for attendees and exhibitors.

New This Year: IMS2022 Systems Forum

- "The Connected Futures Summit," presenting current thinking on next generation wireless technologies at mmWave and THz frequencies, will include presentations, panels and a pavilion on the exhibition floor
- Focused sessions investigating the synergy between radar, phased arrays, and OTA test and applications
- Space 2.0 event highlighting advances in aerospace, the Internet-of-Space and the MTT CubeSat competition

Something for Everyone

- Competitions for best Advanced Practices Paper and Student Paper
- RF Bootcamp intended for students, engineers, and managers
 - new to microwave engineering disciplines
- Workshops and application seminars from our exhibitors, explaining the technology behind their products
- Networking events for Amateur Radio (HAM) enthusiasts,
 Women in Microwaves (WiM), and Young Professionals
- Guest hospitality suite

Important Dates

17 September 2021 (Friday)

PROPOSAL SUBMISSION DEADLINE For workshops, technical lectures, focus and special sessions, panel and rump sessions. Preliminary workshop and technical lecture proposals due 16 July.

7 December 2021 (Tuesday)

PAPER SUBMISSION DEADLINE All submissions must be made electronically.

2 February 2022 (Wednesday)

PAPER DISPOSITION Authors will be notified by email.

9 March 2022 (Wednesday)

FINAL MANUSCRIPT SUBMISSION DEADLINE

Manuscript and copyright of accepted papers.

6 April 2022 (Wednesday)

SLIDE PRESENTATIONS DEADLINE FOR ALL AUTHORS AND PRESENTERS

19-22 June 2022

MICROWAVE WEEK IMS2022, RFIC 2022, ARFTG, and Exhibition





IMS2022 will feature technical sessions, interactive forums, plenary and panel sessions, workshops and technical lectures, application seminars, historical exhibits, and the world's largest RF and microwave industry exhibition.

With more than 9000 participants and 800 industrial exhibits of state-of-the-art microwave products, Microwave Week is the world's largest gathering of RF and microwave professionals.

NEW FOR 2022!

New! Systems Forum

The three-day Systems Forum will highlight the latest in telecommunications, radar and space applications.

New! Industrial Showcase

Papers with industrial authors can showcase their paper and answer questions about their company at the "Industrial Showcase" reception.

New! Industry-Supported Papers

Oral papers from industry-supported work may acknowledge industry sponsorship and/or booth number. Interactive-Forum Poster papers from industry-supported work may distribute approved coupons for prize at associated booth.

New! Industry Paper Contest Prize

Full-page ad in IEEE Microwave Magazine and Microwave Journal.

New! Paper Demonstrations

Authors of Oral and Interactive-Forum Poster papers may request time for live demonstrations in the Interactive Forum.

New! Interactive-Forum Poster Paper Previews

Interactive-Forum Poster papers and demonstrations will be previewed by an oral-session chair for greater visibility.

New! Virtual Content

See virtual previews and tutorials and participate in live events.

New(ish)! Publication in MWCL

The 50 top-ranked papers, as determined by the Technical Paper Review Committee, will be invited to submit the paper to IEEE Microwave and Wireless Components Letters.



SPECIAL STUDENT PROGRAMS

IMS2022 encourages student participation! Visit the website for additional programs.

Student Design Competition:

All eligible students or student teams are invited to consider taking part in the Student Design Competitions (SDCs) during IMS2022. This is the premier IMS event where you cantranslate theory into real hardware and software designs.

Project Connect:

An exceptional group of undergraduate and first-year graduate students from underrepresented groups will be invited to IMS2022 on a travel grant provided by NSF and IEEE through a competitive application process.

PhD Student Initiative:

Available for all first- and second-year PhD students world-wide. The initiative provides sponsorship to attend IMS2022.



Technical Program Committee Members

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Gregor Lasser/Jan Verspecht/Taylor Barton, Student Design Competition Chairs
Elsie Vega, Conference/Event Manager

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Technical Paper Submission

Authors are invited to submit technical papers describing original work and/or advanced practices on RF, microwave, mmWave, and THz theory and techniques. The deadline for submission is 7 December 2021.

Presentation Formats

- 1. Full-length (20 minute) oral papers report significant contributions, advancements, or applications.
- 2. Short (10 minute) oral papers report specific refinements or improvements in the state of the art.
- 3. Interactive-Forum Poster Papers provide a conversational setting where authors may also display hardware and perform demonstrations.

Paper Selection Criteria

There are four selection criteria: Originality, Quantitative Content, Clarity and Interest to MTT-S Membership.

Page Limit

For the initial submission deadline, the paper length should be 3 pages. An accepted paper may be 3 or 4 pages long.

Student Paper Competition

Full-time-student lead authors are encouraged to submit papers for the Student Paper Competition. First, second, and third prizes will be awarded based on content and presentation.

Industry and Advanced-Practice Paper Competitions

Submissions from industrial authors are automatically included in the Industry Competition. Advanced-Practice papers describe innovative techniques in practical aspects of design, processing, measurement or analysis that result in significant improvements in performance and/or time to production. Prizes will be awarded.

Submission Instructions

- 1. All submissions must be in English.
- 2. Authors should adhere to the format provided in the template, which can be downloaded from the conference website.
- 3. The initial submission should be in PDF format, and cannot exceed 4 MB in size.
- on7 December 2021.

Details at www.ims2022.org





Papers are reviewed by IMS2022 Technical Program Subcommittees. A double-blind review process will be used to ensure anonymity for both authors and reviewers.

Notification

Authors will be notified of the decision by 2 February 2022 via email. For accepted papers, an electronic version of the final 3-4 page manuscript along with a copyright assignment to the IEEE must be submitted by 9 March 2022. The Symposium proceedings will be recorded on electronic media and archived in IEEE Xplore.

IEEE T-MTT Special Issue

Authors of all papers presented at IMS2022 can submit an expanded version of their papers to a special symposium issue of the IEEE Transactions on Microwave Theory and Techniques.

Clearances

It is the responsibility of the authors to acquire all required company and government clearances and IEEE copyright forms.

Health and Safety

Please refer to the conference website.

TECHNICAL AREAS:

Electromagnetic Field, Device and Circuit Techniques

- Field analysis and guided waves Novel guiding and radiating structures, new physical phenomena in transmission lines and waveguides, and new analytical methods for solving guided-wave and radiation problems.
- Numerical techniques & CAD algorithms Finite-difference, finite-element, integral equation, and hybrid methods for RF, microwave, and THz applications. Simulation, modeling, uncertainty quantification, and design optimization; circuit-, EM-, multi-physics-, and statistics-based, including surrogate modeling, space mapping, and model order reduction techniques.
- Instrumentation and measurement techniques Theoretically supported and experimentally demonstrated linear and nonlinear measurement techniques for devices and materials, error correction, de-embedding, calibration, and novel instrumentation.
- MHz-to-THz device modeling Active and passive, linear and nonlinear device and structure modeling (physical, empirical, and behavioral) including characterization, parameter extraction, and validation.
- Nonlinear circuit and system analysis, simulation, and design Distortion, stability and qualitative dynamics analysis; circuits and systems (C&S) simulation techniques and applications; behavioral modeling of nonlinear C&S (excluding PAs); and nonlinear C&S design and implementations.
- 6 MHz-To-THz interaction of materials and tissues Electromagnetic field characterization and interaction at molecular, cellular, tissue and living systems levels; MRI and microwave imaging; medical applications; microwave-enhanced chemistry.

Passive Components and Packaging

- Transmission-line structures Novel transmission-line structures and devices, transmission-line equivalent circuits, artificial transmission lines and metamaterial structures, transmission-line applications for devices and systems.
- Passive circuit elements Couplers, dividers/combiners, hybrids, resonators, and lumped-element approaches.
- Planar passive filters and multiplexers Planar passive filters and multiplexers including lumped elements, theoretical filter and multiplexer synthesis methods.
- Non-planar passive filters and multiplexers Resonators, filters and multiplexers based on dielectric, waveguide, coaxial, or other non-planar structures.
- Active, tunable, and integrated filters Integrated (on Si, LTCC, LCP, MCM-D, GaAs, etc.), active, and tunable filters.
- Microwave acoustic, ferrite, ferroelectric, phase-change, and MEMS components Surface and bulk acoustic wave devices including FBAR devices, bulk and thin-film ferrite components, ferroelectric-based devices, and phase-change devices and components. RF microelectromechanical and micromachined components and subsystems.
- Packaging, MCMs, and 3D manufacturing techniques Component and subsystem packaging, assembly methods, inkjet printing, multi-chip modules, wafer stacking, 3D interconnect, and integrated cooling. Novel processes related to 3D printing or additive manufacturing techniques.

Active Devices

- Semiconductor devices and process characterization RF, microwave, mm-wave, and THz devices on III-V, silicon and other emerging technologies. MMIC and Si RFIC manufacturing, reliability, failure analysis, yield, and cost.
- Low-noise amplifiers, variable-gain amplifiers and receivers LNAs, VGAs, detectors, receivers, integrated radiometers, cryogenic amplifiers and models, and characterization methods for low-noise integrated circuits and components.
- Signal generation, modulators, frequency conversion, and signal shaping ICs – CW and pulsed oscillators in silicon and III-V processes including VCOs, DROs, YTOs, PLOs, and frequency synthesizers, signal modulators, and frequency conversion ICs in silicon and III-V processes, such as IQ modulators, mixers, frequency multipliers/ dividers, switches, and phase shifters.
- Mixed-signal and wireline ICs High-speed mixed-signal components and subsystems for transmission; equalization and clock-data recovery techniques for electrical backplanes and electro-optical interfaces. High-speed mixed-signal components and subsystems, including ADC, DAC and DDS technologies.
- High-power MHz, RF and microwave amplifiers Advances in discrete and IC power amplifier devices and design techniques based on III-V and LD-MOS devices, demonstrating improved power, efficiency, and linearity for HF, UHF, VHF, RF and microwave bands (< 26 GHz). Power-combining techniques for SSPA and vacuum electronics.</p>
- Compound semiconductor power amplifiers Advances in IC power amplifier devices, design techniques and power combining based on III-V and other compound semiconductor devices demonstrating improved power, efficiency, and linearity for millimeter-wave bands; vacuum electronics for millimeter-wave.
- Silicon power amplifiers Advances in RFIC and digital power amplifier design and power combining techniques based on silicon CMOS and SiGe processes, demonstrating improved power, efficiency, and linearity for RF, millimeter-wave, and sub-THz bands.

- Linearization and transmitter techniques for power amplifiers Power amplifier design, characterization, and behavioral modeling; linearization and predistortion techniques; envelope-tracking, outphasing and Doherty transmitters for III-V and silicon technologies
- Integrated transceivers, beamformers, imaging and phased-array chips and modules Design and characterization of complex III-V ICs, silicon ICs, heterogenous systems, and related packaging in the RF to mm-wave including narrowband and wideband designs. Innovative circuits and sub-systems for communications, radar, imaging, and sensing applications. Integrated on-chip antennas and on-package antennas.
- Millimeter-wave and terahertz integrated circuits and systems Design and characterization of active components including LNAs, PAs, and frequency conversion ICs in silicon and III-V processes and/or packaging in the upper mm-wave and THz regimes; innovative THz circuits systems for communications, radar, imaging, and sensing applications. Demonstrations of on-chip antennas. Novel multi-feed antennas and antenna-electronics co-designs and co-integrations.
- Microwave photonics and nanotechnology Integrated devices and 1D-2D material-based technology. Multidisciplinary field studying the interaction between microwaves, THz waves, and optical waves for the generation, processing, control, and distribution of microwave, mm-wave, and THz signals. Emerging RF applications of nanophotonics, nanoplasmonics, and nano-optomechanics; nanoscale metrology and imaging.
- HF/VHF/UHF Technologies and Applications Advances in active and passive circuits, components, and systems that operate in the HF, VHF, and UHF frequency ranges.

Systems and Applications

- Phased Arrays, MIMO and Beamformers Technology advances combining theory and hardware implementation in the areas of phased-array antennas, integrated beamformers, spatial power combining, retrodirective systems, built-in self-test techniques, broadband arrays, digital beamforming, and multi-beam systems. New beamforming, beam-tracking, and spatial notching algorithms, signal processing, and demonstrations.
- Radar and Imaging Systems RF, millimeter-wave, and sub-THz radar and imaging systems, automotive radars, sensors for intelligent vehicular highway systems, UWB and broadband radar, remote sensing, radiometers, passive and active imaging systems, radar detection techniques, and related signal processing.
- Wireless System Characterization and Architectures for 5G and Beyond RF, millimeter-wave, and sub-THz communication systems with hardware implementation for terrestrial, vehicular, satellite, and indoor applications, point-to-point links, backhaul and fronthaul applications, radio-over-fiber links, cognitive and software-defined radios, MIMO, massive MIMO, full-duplex technologies, simultaneous transmit and receive (STAR) systems, shared and novel spectrum use, waveform design, modulation schemes, and channel modeling.
- Sensing and RFID Systems Short range wireless and RFID sensors, gas and fluidic sensors, passive and active tags from HF to millimeter-wave frequency, RFID systems including wearables and ultra-low-power.
- Wireless Power Transmission Energy harvesting systems and applications, rectifiers, circuits, self-biased systems, combined data and power transfer systems
- MHz-to-THz instrumentation for biological measurements and healthcare applications Devices, components, circuits and systems for biological measurements and characterizations; biomedical therapeutic and diagnostic applications; systems and instrumentation for biomedical applications; wireless sensors and systems, and implantable and wearable devices for health monitoring and telemedicine.
- AI/ML for RF and mmWave AI/ML algorithms, implementations, and demonstrations for spectrum sensing, mobile edge networking, and MIMO and array beam operations and management; AI/ML algorithms for design and optimization of RF/mmWave components, circuits, and systems; AI/ML algorithms for in-situ sensing, diagnostics, control, reconfiguration, and optimization of MHz to THz communication and sensing circuits and systems.

Emerging Technologies

- Innovative systems and applications Emerging technologies and novel system concepts for RF/microwave applications such as 6G, Internet of Things (IoT), Internet of Space (IoS), wearable computing/communication systems, machine-to-machine (M2M) communication, intelligent transportation, smart cities, smart environment, heterogeneous integration and 3D ICs, silicon photonics and plasmonics.
- MHz-to-THz physical layer security Devices, circuits, and systems for secured communication and sensing from MHz to THz, addressing general security vulnerability due to electromagnetic emissions, hardware and software co-design for physical layer security, advanced devices and materials to enhance RF, mm-Wave, and THz physical layer security, trusted design, fabrication, packaging, and validation for RF, mm-Wave, and THz electronics.
- Quantum devices, systems, and applications Cryogenic RF devices, circuits, systems and interfaces for quantum computing and sensing applications.

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- Special focused highlights, including WIM Panel **Session; Mobility Closing Panel with Competition** results and 3MT Competition
- Industry workshops and MicroApps
- Expo auditorium with Industry Track
- Connected Future Summit (formerly 5G Summit)
- Networking events



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COMPONENTS

Ceramic Chip Inductors



AVX Corp. released a new series of ultra-miniature multilayer ceramic chip inductors for high

frequency RF applications. The new LCCI Series inductors are currently available in three standard EIA chip sizes—0201, 0402 and 0603—with tight-tolerance physical dimensions almost exclusively in the submillimeter range and tin-plated surfacemount terminations, enabling compatibility with high density PCBs and reflow soldering in space- and weight-constrained applications within the telecommunications and networking markets, as well as with lead-free and RoHS directives.

AVX Corp. www.avx.com

Programmable Attenuator VENDORVIEW

The new 50P-2101 programmable attenuator from JFW has an increased attenuation



range of 0 to 63.5 dB with the precision of 0.5 dB steps. It operates from 100 MHz to 18 GHz and is guaranteed monotonic across the

entire band. +5 V DC supply and TTL logic control allow for easy integration into any communications, EW, satcom or radar RF test system. Switching speed is 1 microsecond maximum and SMA female connectors are standard.

JFW Industries Inc. www.jfwindustries.com

Specialty Components



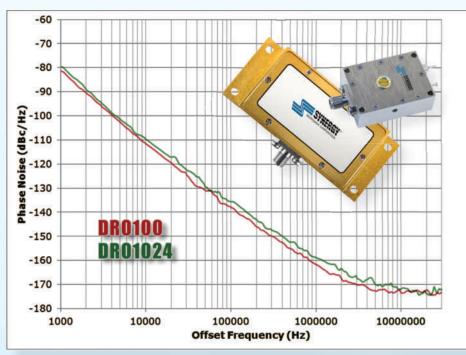
Knowles Precision Devices is a specialty components manufacturer, which means we choose to

take on the complex challenges that come with high reliability, high temperature, high performance and high frequency solutions. Knowles offers a wide range of microwave products, including custom designed and build-to-print solutions to meet the needs of aerospace and defense customers. Its 5G catalog filters at 26, 28 and 39 GHz provide 3 GHz of bandwidth, $>50~{\rm dB}$ rejection, are $20\times$ smaller and are temperature stable from -55°C to +125°C.

Knowles Precision Devices www.knowlescapacitors.com



Exceptional Phase Noise Dielectric Resonator Oscillator



Available In Surface Mount.



For extended temperature range (-40° to 85° C)

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Model	Frequency (GHz)	Tuning Voltage (VDC)	DC Bias (VDC)	Typical Phase Noise @ 10 kHz (dBc/Hz)
Surface Mount Models		,		
SDRO800-8	8.000	1 - 10	+8.0 @ 25 mA	-110
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
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
KDRO145-15-411M	14.500	*	+7.5 @ 60 mA	-100

^{*} Mechanical tuning only ±4 MHz

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- •FILTERS/DIPLEXERS/SOURCES
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- **•SWITCHES UP TO 160GHz**
- **•PHASE SHIFTERS UP TO 160GHz**
- TRANSITIONS/ADAPTERS UP TO 500GHz
- WAVEGUIDE PRODUCTS UP TO
 1THz
- TERMINATIONS/LOADS UP TO 325GHz
- •MIXERS UP TO 500GHz



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- POWER COMBINERS/DIVIDERS EQUALIZERS
- CABLE ASSEMBLIES/
 CONNECTORS UP TO 110GHz
- •SUB-SYSTEMS UP TO 110GHz
- **•DETECTORS UP TO 500GHz**
- •UMITERS UP TO 160GHz
- •BIAS TEE UP TO 110GHz

Add:1710 Zanker Road Suite 103,San Jose, CA 95112 Tel: (408) 541-9226 Fax:(408) 541-9229 www.cernex.com www.cernexwave.com E mail: sales@cernex .com

NewProducts

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, drones and a variety of military and commercial test applications. **Micro Lambda Wireless**

www.microlambdawireless.com

Attenuator Programs VENDORVIEW



Mini-Circuits' model RCDAT-50G-30 is a programmable attenuator with an attenuation range of 0 to 31.5 dB in 0.5 dB steps from 100 MHz to 50 GHz. It can

be controlled via USB or Ethernet connection, with a single interconnection enabling independent control of multiple attenuators in a master/slave configuration. Typical insertion loss at 0 dB attenuation is 3.25 dB from 100 MHz to 15 GHz, 6.0 dB from 15 to 35 GHz and 8.0 dB from 35 to 50 GHz, while typical full-band VSWR is 1.50:1 or better from 25 to 50 GHz. Ideal for measurement and communications systems, the RoHS-compliant attenuator features typical transition time of 100 ns.

Mini-Circuits
www.minicircuits.com

Ultra-Wide Bandpass Filters



RLC Electronics is manufacturing ultra-wide bandpass filters to help customers pass broadband filtering

requirements with over 70 percent bandwidths (up to 160 percent). These multi-octave filters are available from low frequency up to 40 GHz. The unit pictured above is an 18 to 40 GHz bandpass filter, with low loss (0.8 dB maximum), sharp rejection (45 dB at 10 GHz and 48 GHz) and a small footprint (1.2" plus connectors). Other custom options are available depending on customer requirements, including high-power ultra-wide bandpass filters.

RLC Electronics
www.rlcelectronics.com

WR-19 Waveguide Lowpass Filter



Spacek Labs model LPF1-U-15C lowpass filter has a passband from 38 to 64 GHz in WR-19 waveguide with 1.85 mm coaxial guide I/O available). The filter is 1.3 in. long and has an insertion loss of 1.5 dB typical and 2.5 dB maximum. The rejection at 84 GHz is 30 dB minimum. This proprietary filter design rejects frequencies from 85 to 170 GHz by greater than 40 dB.

Spacek Labs www.spaceklabs.com

RF and Microwave Filters



TTE Filters, a designer and manufacturer of RF and microwave filters for high performance applications,

announced that its Instec Filters brand ML61 EMI/RFI filters are now qualified to the U.S. DoD DLA Land and Maritime's MIL-PRF-28861 military standard. This series can now be used in military electronic systems to suppress and reduce broadband RF interference which would otherwise compromise system performance. These high performance systems are utilized in military communication devices, oscillators, attenuators and low noise amplifiers.

TTE Filters www.tte.com

CABLES & CONNECTORS

Adapters







Withwave's 2.4 mm (M) to SMPM (F) adapter is manufactured to precise

microwave specifications and constructed with male gender on side 1 and female gender side 2. The precision microwave connector interfaces ensure an excellent microwave performance up to 50 GHz. Features include a frequency range of DC to 40 GHz, VSWR (maximum): 1.40 : 1 and body: stainless steel (passivated).

withwave co. Itd www.with-wave.com

AMPLIFIERS

40 W SSPAs VENDORVIEW



Exodus Advanced Communications 26.5 to 40.0 GHz, 40 W solid-state power amplifiers (SSPAs) are replacing aging TWT amplifiers. Designed

for general EMC testing applications as well as Mil-Std 461(RS103) standards. Exodus Model AMP4066-LC is a compact 6U design providing superb RF performance with unprecedented P1dB power as compared to TWTs. They provide 46 dB minimum gain, -20 dBc harmonics as well as gain control with < 10 dB noise figure. Exodus offers a full range of 10, 20, 40, 60 and 100 W

Exodus Advanced Communications www.exoduscomm.com



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Parameter	Unit	Value
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Dowlink Frequency Band	GHz	18 to 24
Max Insertion Loss	dB	4 Downlink 5 Uplink
I/P & O/P VSWR		1.6:1
Gain Flatness	dB	1.0
Port to Port Variation	dB	1.0
Port to Port Isolation	dB	25



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www.etiworld.com

NewProducts

Low Noise Amplifier VENDORVIEW



PMI Model No, PEC-42-1G40G-20-12-292FF-BT is a 1 to 40 GHz low noise amplifier that has a typical gain of 40 dB while maintaining a

±2.5 dB flatness. Bias can be applied via the output RF connector or DC pin and comes in a small 1.37" × 1.00" × 0.60" package outfitted with 2.92 mm female connectors

Planar Monolithics Industries www.pmi-rf.com

100 W QFN Amplifier **VVENDORVIEW**



RFMW announced design and sales support for a C-Band RF amplifier from Qorvo. The QPA2309 power amplifier offers

100 W of pSat RF power from 5 to 6 GHz in a small 7×7 mm QFN package. With ~ 50 percent power added efficiency, the QPA2309 runs from a 50 V supply and delivers 22 dB of power gain for civilian and military radar applications supporting both CW and pulsed operation. 100 percent DC and RF tested on-wafer to ensure compliance to electrical specifications.

RFMW www.rfmw.com

Amplifier System Accessories



KIT-EMPOWER1KW is comprised of several accessories required to put the 1 KW family

of amplifiers from Empower RF into service. The OG cables from Gore provide durable, repeatable, reliable performance. The high-power TRU-500 cables from TRU are required to handle the 1 KW of CW power provided at 1,000 MHz. The broadband. high-power directional coupler from IPP is ideal for power monitoring at the output of the amplifier. Each of the components included in the kit are also separately available for customers requiring a different configuration.

Richardson RFPD www.richardsonrfpd.com

Power Transistors



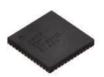


Tagore Technology introduces the TA9 \times 10 \times series of GaN RF PA power transistors ranging from 6 to 25 W Psat. These transistors are

capable of operating up to 4 GHz. Using a simple input/output match, they can be tuned for best power and efficiency. Package sizes range from 3 \times 3 mm to 6 \times 5 mm QFN. The TA9×10x series are well suited for a range of applications including public safety, military radios, radar and cellular infrastructure.

Tagore Technology www.tagoretech.com

Two-Stage MMIC



Wolfspeed enables high performance RF power solutions with the new CMPA801B030S. It is a two-stage MMIC designed in Wolf-

speed's GaN on SiC, 28 V, 0.15 µm process. Packaged in a $7 \times 7 \text{ mm QFN}$ to allow for reduced board area and high-throughput manufacturing lines. Operating from 8 to 11 GHz, it offers over 35 W of output power, 35 percent power added efficiency and 20 dB power gain. This device can support a wide range of X-Band radar applications across air-borne, ship-borne and ground-based platforms.

Wolfspeed www.wolfspeed.com

SYSTEMS/SUBSYSTEMS

QUAD-MxFE Platform Evaluation Boards VENDORVIEW



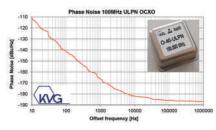
The Quad-MxFE System Development Platform contains four MxFE® software defined, direct RF sampling transceiv-

ers, as well as associated RF front-ends, clocking and power circuitry. The target application is phased array radars, electronic warfare and ground-based satcom, specifically a 16 transmit/16 receive channel direct sampling phased array at L-/S-/C-Band (0.1 GHz to ~5 GHz). The Rx and Tx RF front-end has drop-in configurations that allow for customized frequency ranges, depending on the user's application.

Analog Devices www.analog.com

SOURCES

Ultra-Low Phase Noise OCXO



KVG has launched a new revision of its ultra-low phase noise (ULPN) 100 MHz OCXO 0-40-ULPN-100M series. Based on latest oscillator technology and noise improved SC-cut crystals KVG's engineers have now achieved ultra-low phase noise performance in combination with tight frequency stability. This 100 MHz ULPN OCXO offers excellent phase noise performance near the carrier with better than -138 dBc/Hz at 100 Hz as well as a very low noise floor of -185 dBc/Hz. KVG

www.kvg-gmbh.de



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The waveguide quick connect is used to connect and disconnect mating flanges of waveguides efficiently and reliably without any complications. It uses thumb screws to effortlessly clamp two flanges together to create a perfect connection for two mating waveguides that eliminates tedious waveguide screw alignments to avoid signal leakage and impedance mismatch due to waveguide mating misalignment.

It also solves test setups where the flange connections are restrictive and do not provide enough room for the standard waveguide screws or screwdriver to operate.

Two models, **SWH-QC-0750C-R2** and **SWH-QC-1125C-R2**, are offered to take care of standard UG-383/U through UG-385/U, and UG-387/U flanges to cover waveguide connections in the frequency range of **33 GHz to 1 THz.**





NewProducts

Voltage Controlled Oscillators VENDORVIEW



Pasternack has just launched a new series of voltage controlled oscillators (VCOs) designed to address a wide range of electronic warfare. ECM, VSAT, satcom,

radar and test and measurement applications. Pasternack's 15 new coaxial packaged VCOs cover broad frequency bands and exhibit excellent phase noise, tuning linearity and harmonic suppression performance. These VCOs are ideal for test and measurement and signal conversion applications in transceiver circuits. VCOs generate their own output signal level and

allow designers to adjust the tuning voltage, which varies the output signal oscillation frequency to get a desired signal level across a specific frequency band.

Pasternack www.pasternack.com

Solid-State Microwave Generator



RFHIC's RIM251K6-20G is a 1.6 kW. GaN solid-state microwave generator operable from 2,400 to 2,500 GHz. The modular

structure GaN solid-state microwave generator is built using RFHIC's cutting edge GaN on SiC transistors providing excellent thermal stability and efficiency. The RIM251K6-20G is built with a high-grade phase lock loop synthesizer, creating the desired frequency signal in a precise and stable manner. The RIM251K6-20G is equipped with RFHIC's control software suite allowing users to digitally monitor and control the generator's frequency, power and signal source.

RFHIC

www.rfhic.com

SOFTWARE

Modelithics COMPLETE+3D Library VVENDORVIEW



Piconics and Modelithics announced the availability of three new 3D geometry models for the CC19T40K240G5-C.

CC21T36K240G5-C and CC45T47K-240G5C2 conical inductors from Piconics. These models are all included in the latest version, v21.1, of the Modelithics COMPLETE+3D Library for Ansys®HFSSTM. The new models are validated through multi-substrate S-parameter measurements. Each model is validated through 67 GHz, making them well suited for broadband applications. The CC19T40K240G5-C conical inductor has an inductance value of 0.220 µH and a maximum current rating of 700 mÅ.

Modelithics Inc. www.modelithics.com

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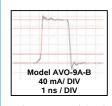


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TEST & MEASUREMENT

E-Band VNA Extender VENDORVIEW



ST0-12203-U6 is an E-Band VNA frequency extender that extends VNA frequency range to 60 to 90 GHz for full two-port,

S-parameter testing. It is compatible with modern vector network analyzers such as the Rohde & Schwarz ZVA24, Anritsu VectorStar, Keysight PNA-X Series and Copper Mountain CobaltFx C4220. The NIST tracible calibration kit, STQ-TO-12-S1-CKIT1, is highly recommended to complete the E-Band VNA test set.

Eravant www.eravant.com

Vector Network Analyzers VFNDORVIEW



Rohde & Schwarz launched the R&S ZNA originally two years ago. The newly introduced models cover frequency

ranges of up to 50 GHz and 67 GHz. The R&S ZNA features excellent RF performance, including wide dynamic range and extremely low trace noise, and comes with a user-friendly, purely touch-based GUI. Its unique hardware platform offers up to four internal, phase coherent sources plus a fifth source which can be used as a second internal local oscillator or as an additional source for measurements on mixers.

Rohde & Schwarz GmbH & Co. KG www.rohde-schwarz.com

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BookEnd



Machine Learning Applications in Electromagnetics and Antenna Array Processing

Manel Martínez-Ramón, Arjun Gupta, José Luis Rojo-Álvarez, Christos Christodoulou

achine learning (ML) has seen a meteoric rise in research and applications in the past decade owing to the increased computation prowess of modern computers and a vast amount of information captured about various aspects of work and life. Written by experts in the field, this book provides a comprehensive overview of state-of-the-art ML approaches for a range of disciplines in signal processing, communications and electromagnetics. Readers will find detailed explanations and relevant examples of the underpinnings of ML principles and common ML architectures such as support vector machines, Gaussian processes, nonlinear kernels, deep learning architectures such

as multilayered perceptrons, convolutional neural networks, recurrent neural network, long short-term memory and autoencoders.

Once the trends and methods in ML are established, the book dives into some of the major applications of these methods in signal processing and electromagnetics. Detailed applications of the algorithms for solving a variety of problems are explored, including antenna array beamforming, angle-of-arrival detection, computational electromagnetics, antenna optimization and reconfigurable antennas for cognitive radio using ML and computer vision. The most recent research methods and algorithms are presented.

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Home to Benchmark Lark Technology's RF and High Speed Design Center of Innovation, Benchmark Phoenix offers customers the ability to rapidly iterate to overcome SWaP-C challenges to advance applications from 5G telecommunications to missile guidance systems. Seamless integration with Benchmark's global manufacturing network gives customers a wide range of options to meet production cost/volume, country of origin or market proximity goals. The Phoenix facility is ISO 9001, AS9100 and ANSI ESD 20:20 certified and ITAR/EAR compliant.

The facility features HDI circuit topologies and modified semi additive processes (mSAP) with 25 micron feature capability; a variety of final finish plating finishes; stacked and staggered micro vias; state-of-the-industry laser direct imaging; automated plating processes; high performance material sets such as liquid crystal polymer (LCP), PTFE, other thermoset and thermoplastic systems and hybrids; automated die attach with seven micron placement accuracy; automated wire/ribbon bonding; assembly/ test in ISO 7 cleanroom; jet dispense underfill/encapsulation/dam and fill; stacked die packaging; CSAM acoustic

shear; and wire pull analytics. There is also a full slate of SMT assembly and integration capabilities including analysis and inspection equipment.

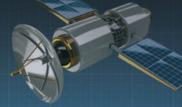
Co-located microelectronic and SMT assembly services also ensure that advanced designs can be scaled to required production levels rather than being constrained by fragmented production through multiple suppliers. A case study that demonstrates their expertise includes how market pressures have driven more functionality into smaller devices to the point where conventional partitioning has been the limiting factor. Benchmark Phoenix engineers overcame this design limitation by applying the latest advances in thin dielectric materials and HDI fabrication processes to provide superior signal integrity, enabling non-traditional partitioning while avoiding crosstalk and interference. Benchmark has invested in the materials and processes necessary to create PCBs with 25 micron features in advanced hybrid constructions of more than ten layers, enabling performance up to 110 GHz.

Benchmark Lark Technology is also using the unique features of materials like LCP to greatly reduce the size of circuits, while at the same time improving their performance. This type of approach has allowed Benchmark Lark Technology to shrink laptop size computers down to small cubes and transformed larger microstrip bandpass filters into small, surface mountable LCP stripline filters, which achieves a significant reduction in SWaP-C. In one example, a filter measures 0.25" x 0.25" x 0.032" and weighs only 0.0032 oz, which is 5x lighter than an interdigital microstrip bandpass filter fabricated on another substrate. Lark is currently developing new microwave and mmWave filters at frequencies up to 40 GHz using LCP to deliver high performance and optimize for size, weight and power.

Benchmark's mission is to be their customers' trusted partner; providing comprehensive solutions across the entire product lifecycle; leading through innovative technology and engineering design services; leveraging an optimized global supply chain; and delivering world-class manufacturing services and Benchmark Phoenix embodies this mission.

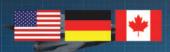
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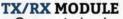
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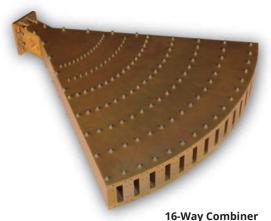
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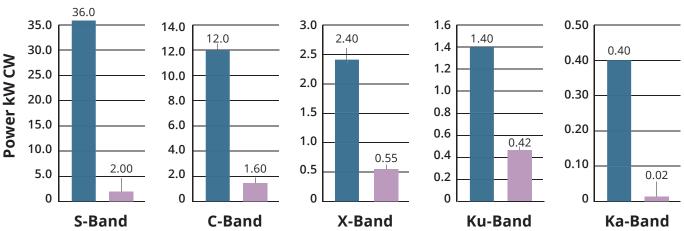
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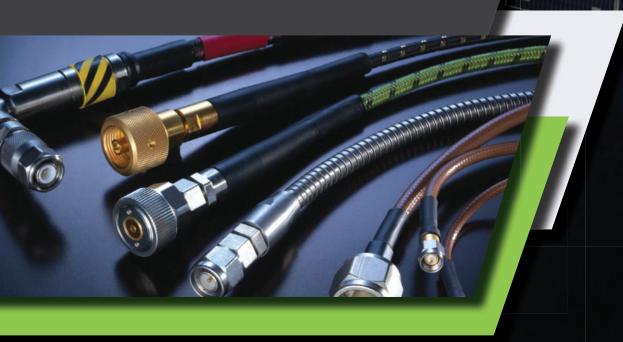


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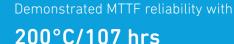
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Providing Simultaneous Transmit and Receive Capabilities for Defense Systems

Mark Hickle

BAE Systems, Nashua, N.H.

early all RF systems require the capability to both transmit and receive. Even receive-only systems often coexist with other transmitters located on the same platform (see *Figure 1*). To optimally use the available bandwidth, it is highly desirable to be able to transmit and receive at the same time



▲ Fig. 1 Simultaneously transmitting and receiving at the same frequency is a capability required by many military platforms.

on the same frequency. This capability is usually referred to as simultaneous transmit and receive (STAR) or in-band full-duplex (IBFD). The unfortunate reality is, in most cases, the laws of physics prevent simultaneous, same frequency operation of co-located transmitters and receivers. Transmit (Tx) and receive (Rx) signal levels can differ by more than 10 orders of magnitude, requiring >100 dB isolation between Tx and Rx channels to achieve true STAR/IBFD operation. Tx powers can range from +20 to +50 dBm, while Rx signal power levels range from -100 to -50 dBm. Typical isolation between physically separate Tx and Rx antennas—or through antenna interface circuits such as circulators—falls far short of the required isolation. In the worst case, high-power Tx leakage at the receive input can physically damage sensitive RF electronics if the Tx power is high and the isolation between antennas is poor. This is particularly problematic at mmWave frequencies and in systems with wideband data converters, which tend to have inherently low immunity to high-power signals.

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In such situations, the strength of the self-interference must be reduced in the analog domain to prevent damage to the hardware. With lower Tx power or higher antenna isolation, the selfinterference signal strength may be low enough to not cause damage to the electronic components, but it can still substantially degrade receiver performance. Transmitter interference can exceed the receiver's dynamic range by orders of magnitude, causing a host of problems such as gain compression, intermodulation distortion and increased noise figure, decreasing the receiver's sensitivity and dynamic range. The strength of the self-interference must be reduced in the analog domain to prevent these non-ideal effects. Even if the non-ideal hardware effects can be prevented, the transmitter leakage can still be orders of magnitude higher than the signals of interest, degrading the signal-to-noise ratio and masking the desired signals.

Overall, systems must have 50 to 80 dB Tx/Rx isolation to prevent distortion and possible damage to the receiver front-end and 100 to 150 dB isolation

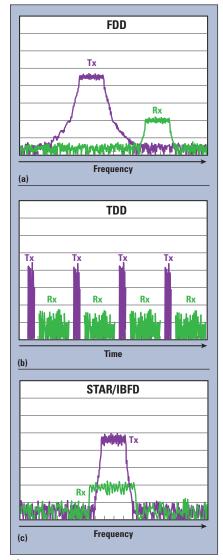
to ensure Tx leakage is below the noise floor of the receiver. As physical antenna isolation alone rarely provides this isolation, the remaining options to achieve "peaceful" Tx/Rx coexistence

- Reduce the transmit power level or add attenuation to the receiver
- Use separate frequencies for Tx and Rx with RF filtering to achieve the required isolation, i.e., frequencydomain duplexing (FDD), illustrated in *Figure 2a*
- Restrict Tx and Rx to non-overlapping timeslots, i.e., time-domain duplexing (TDD), shown in Figure 2b
- Apply knowledge of the Tx signal to actively cancel transmitter leakage, i.e., STAR/IBFD (see Figure 2c).

Simply reducing the Tx power or adding attenuation to the receiver severely compromises system capabilities and are usually not acceptable options. However, in certain situations—particularly those severely size, weight and power constrained—this may be the only viable option.

FDD and TDD are the most common methods today, used in nearly all

communication systems, radars and other transceivers. FDD systems use separate predefined frequency bands for the Tx and Rx channels (see Figure 2a). RF filters provide Tx/Rx isolation to prevent saturation of the RF front-end. and additional filtering at the intermediate frequencies (IF) and baseband (BB) provides the necessary > 100 dB isolation between Tx and Rx channels. TDD systems use RF switches to electrically disconnect the transmitter and receiver from the antenna interface during their respective idle timeslots to prevent receiver damage (see Figure 2b). TDD systems have a bit more flexibility than FDD systems, as they can accommodate asymmetric uplink/downlink data



▲ Fig. 2 Frequency domain (a) and time domain (b) duplexing cannot use the full information capacity of the bandwidth in a channel. Theoretically, STAR at the same frequency (c) provides twice the channel capacity of half-duplex systems.

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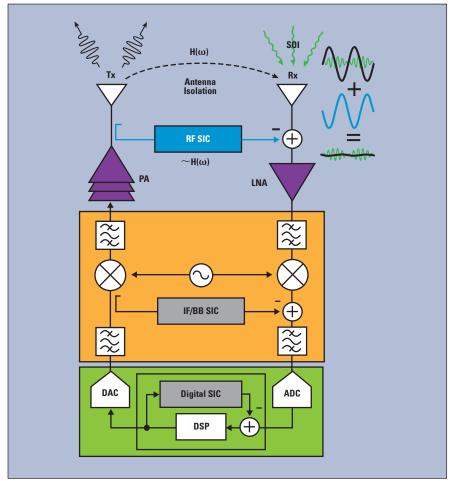
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▲ Fig. 3 SIC techniques subtract a copy of the transmit signal from the receiver signal. It can be implemented at RF, IF, baseband or after data conversion.

rates by adjusting the relative lengths of the Tx and Rx time slots. FDD systems, on the other hand, are restricted by fixed channel filter bandwidths. Though FDD and TDD are used widely, both duplexing schemes have serious drawbacks: bidirectional communication systems using FDD and TDD are only able to use half of the theoretical full-duplex channel capacity, the use of TDD in pulsed radar creates blind range bins which degrade system performance and both TDD and FDD in electronic warfare (EW) decrease the probability of intercepting threat signatures.

Active self-interference cancellation (SIC) is the most general solution which can theoretically enable STAR/IBFD, albeit the most challenging to implement. It ideally improves Tx/Rx isolation without compromising Tx power and Rx sensitivity or placing restrictions on when or how the transmitter and receiver can operate. Active SIC takes a copy of the Tx signal, processes it so that it has the same magnitude and phase as the Tx leakage at the re-

ceiver input, then subtracts it from the Rx signal path to cancel the Tx leakage. This can be performed in the analog or digital domain or a combination of the two. If the coupling channel is modeled perfectly, the Tx leakage is perfectly cancelled, realizing infinite isolation between the Tx and Rx channels. The potential benefits of STAR/IBFD have attracted significant investment and research activity from government, industry and academia.

PRESENT CAPABILITY

As the first line of defense, researchers have developed many techniques for achieving high levels of raw isolation between Tx and Rx antennas. These include cross-polarized antenna pairs, frequency-selective surfaces, novel circulator structures and beamforming networks to create near-field nulls. In some instances, these techniques can provide up to 60 dB of native antenna isolation, ¹ which may be sufficient to protect the RF electronics from dam-

age or saturation but is rarely sufficient to fully realize same frequency STAR. Additional techniques are required.

The next line of defense to protect receivers from self-interference is analog SIC circuitry (see Figure 3). Analog SIC is attractive because it has the potential to reduce the magnitude of self-interference prior to the sensitive receiver components, protecting them from possible distortion, saturation and damage. Analog cancellation can be performed in the RF domain prior to the low noise amplifier or other circuitry, or it can be performed later in the receiver's signal chain at IF or BB. Cancellation at RF and prior to any active circuitry protects all of the receiver's circuitry from strong self-interference, where IF and BB cancellation only protect a subset of the receiver's circuitry. However, implementing cancellation circuitry at RF is more challenging than at IF and BB, as component losses and noise tend to worsen with increasing frequency. A combination of RF, IF and BB cancellation can be used to provide higher levels of cancellation while protecting the entire receiver signal chain.²

The prevailing method for implementing analog SIC is to tap off a portion of the Tx signal, process it so that it has the same magnitude but opposite polarity as the leakage, then inject it back into the receiver input to cancel the transmitter leakage. As this is a vector cancellation, the canceller must accurately replicate the magnitude and phase of the self-interference (SI) channel's transfer function over the system's instantaneous bandwidth. In narrowband systems, the canceller circuitry can be as simple as a phase shifter and attenuator, set to match the amplitude and phase of the SI channel. However, this generally only provides cancellation at a single frequency or narrow band, since the group delay of the SI path causes the phase of the SI path and the canceller path to diverge as the frequency range widens.

Several wideband cancellers have recently been demonstrated, using technologies such as coaxial delay lines and switched-capacitor delay lines to match the delay of the SI path. Several of these implementations contain multiple signal paths, each with its own delay and weight. This allows the canceller to account for multiple SI coupling paths, such as where near-field scattering objects result in multipath coupling with a non-zero spread in delay values. Other implementations use frequency-domain equalization, in which multiple



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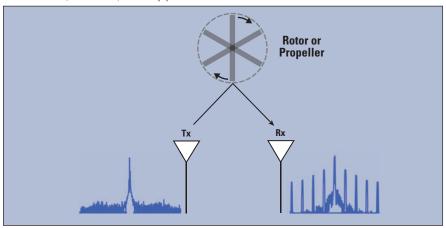
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narrowband filters with configurable amplitude, phase and delay are combined to approximate the amplitude and phase of the SI path transfer function over a given bandwidth. Combined analog SIC at both RF and BB has yielded 30 to 50 dB of cancellation across 20 to 100 MHz bandwidths.²⁻⁴ Combined with antenna isolation, this is often sufficient to prevent saturation of the receiver; however, it rarely provides

enough total isolation to facilitate same frequency STAR.

Digital SI is the last method used to cancel undesired Tx leakage. Digital cancellation operates much like analog cancellation: it passes the known Tx waveform through a digital filter which emulates the SI coupling channel's transfer function, then subtracts the resulting signal from the receiver input. Digital SIC is inherently more flexible

than analog cancellation because it can perform a variety of signal processing functions without adding noise or distortion. A primary limitation of digital SIC is it relies on the self-interference being digitized without prior distortion or damage in the receiver. It is not a substitute for the various analog methods of SIC, rather a complementary approach which can help achieve the > 100 dB total isolation required for STAR/IBFD. A second drawback of digital SIC is its increasing complexity as signal bandwidth increases. Digital SIC has been demonstrated to nearly 100 MHz signal bandwidths, but it has not achieved the > 1 GHz signal bandwidths required by many military systems.



▲ Fig. 4 Rotating scattering objects can introduce micro-Doppler sidebands to the received signal, complicating SIC.



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COMMERCIAL VS. DEFENSE

Researchers have made incredible progress toward IBFD communications systems for commercial requirements. However, current SIC systems fall significantly short of the performance required for many defense applications. Some defense systems are similar to their commercial counterparts, while others have performance requirements far beyond those of typical commercial systems. Examples include:

Instantaneous bandwidth State-of-the-art SIC circuits provide relevant levels of Tx/Rx isolation to approximately 100 MHz instantaneous bandwidth.⁵ These bandwidths are sufficient for many commercial communications applications, which have typical channel bandwidths from 20 to 80 MHz. With the advent of multi-GSPS analog-to-digital converters, many defense systems require SIC over several GHz of instantaneous bandwidth-orders of magnitude greater than current SIC systems. One of the main challenges to achieving cancellation over these bandwidths is realizing compact, low loss delay elements that match the delay of the physical coupling distance between Tx and Rx antennas. SIC circuits require variable delay elements with large delay range and fine resolution to match complex multipath antenna coupling environments, yet current variable delay elements pose unfavorable tradeoffs among size, loss and bandwidth.

Transmit power handling — The best SIC systems have demonstrated power handling less than 30 dBm.³ While this is acceptable for certain low power applications, such as cellular handsets and local wireless networks, many defense requirements exceed current capabilities by orders of magnitude, i.e., Tx powers from 40 to 60 dBm.



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Frequency agility — Commercial systems typically operate on fixed, predefined frequency bands. This bounds the solution space for SIC systems, significantly reducing the complexity to a prescribed frequency and instantaneous bandwidth. Military systems, however, are trending to wideband frequency agility: certain communication systems must support multi-band operation spanning wide frequency

ranges. Low probability of intercept radar and secure communications rely on frequency hopping or other frequencyagile methods. EW systems must be configured to cover many frequency bands to provide threat monitoring and mitigation over the full spectrum.

Multipath environments — SIC systems must cancel reflections from nearby scattering objects, as these reflections can have similar magnitudes

to the direct coupling between antennas. These complex multipath environments present challenges when there is a large spread in the delays among the various coupling and scattering paths. The SIC circuitry must produce equivalent delays to those of the coupling paths, and it is challenging to create the required delays in a compact, low loss form.

Doppler shift — SIC in the presence of multipath is further complicated when the environment surrounding the antennas is not static. Variation of the coupling environment over time poses multiple challenges. First, it places a limit on the reconfiguration speed of the cancellation system, as the SIC must adapt to the coupling environment at roughly the same rate as the environment changes. Time-varying multipath can introduce Doppler frequency shifts, depending on the wavelength of interest and the velocity of the time-varying object. Helicopter rotors and aircraft propellers are common items that can create micro-Doppler sidebands on the SI signal (see Figure 4). For example, a typical 20 m diameter helicopter rotor rotating at 250 revolutions per minute creates a Doppler shift of some 9 kHz on a 10 GHz carrier. These Doppler sidebands add significant complications, as the cancellation hardware must either match the frequency shift with circuitry that translates the frequency or senses the channel phase variations and quickly updates the hardware.



The U.S. Department of Defense (DoD) has invested heavily in wideband, high-power, widely reconfigurable RF devices and systems over the past several decades. Examples include DARPA Microsystems Technology Office programs such as RF Field-Programmable Gate Array (RF-FPGA), Technologies for Mixed-mode Ultra Scaled Integrated Circuits (T-MUSIC), Arrays at Commercial Timescales and Signal Processing at RF (SPAR). The maturity of STAR capabilities has not kept pace with these advancements, leaving a capabilities gap with many current and future systems.

The path to closing this gap requires a substantial investment to address the challenges outlined in this article. Approaches may include the development of new RF materials with higher power handling or lower loss, new circuit architectures breaking the fundamental tradeoffs between group delay and bandwidth, frequency-translational architectures which enable cancellation



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of Doppler SI or fast closed-loop control algorithms adapting to rapidly-changing antenna coupling environments. Recognizing this critical technology gap, the DoD recently began investing in scaling the performance of STAR technologies to the levels required by military systems. The DARPA Wideband Adaptive RF Protection (WARP) program is the most recent example, accompanied by several SBIR/STTR programs spon-

sored by various services.

BAE Systems is focused on advanced electronics for DoD applications, with a rich portfolio of advanced defense electronics programs such as DARPA RF-FPGA, CONCERTO, TMUSIC and others. The company was recently awarded two contracts on the DARPA WARP program to develop widely-tunable filters and broadband SIC cancellation systems, which are

addressing many of the issues described in this article. The capabilities developed on these programs will enable interference mitigation capabilities for BAE Systems' suite of advanced reconfigurable RF electronics and provide more capable and robust systems to protect the warfighter.

References

- K. E. Kolodziej, P. T. Hurst, A. J. Fenn and L. I. Parad, "Ring Array Antenna with Optimized Beamformer for Simultaneous Transmit and Receive," Proceedings of the 2012 IEEE International Symposium on Antennas and Propagation, Chicago, III., 2012, pp. 1–2.
- A. Nagulu et al., "A Full-Duplex Receiver with True-Time-Delay Cancelers Based on Switched-Capacitor-Networks Operating Beyond the Delay-Bandwidth Limit," IEEE Journal of Solid-State Circuits.
- K. E. Kolodziej, B. T. Perry and J. S. Herd, "In-Band Full-Duplex Technology: Techniques and Systems Survey," *IEEE Transactions on Microwave Theory* and Techniques, Vol. 67, No. 7, July 2019, pp. 3025–3041.
- A. El Sayed et al., "A Full-duplex Receiver with 80 MHz Bandwidth Self-interference Cancellation Circuit using Baseband Hilbert Transform Equalization," IEEE Radio Frequency Integrated Circuits (RFIC) Symposium, Honolulu, Hawaii, 2017, pp. 360–363.
- D. Korpi, M. Heino, C. Icheln, K. Haneda and M. Valkama, "Compact Inband Full-Duplex Relays With Beyond 100 dB Self-Interference Suppression: Enabling Techniques and Field Measurements," *IEEE Transactions on Antennas and Propagation*, Vol. 65, No. 2, February 2017, pp. 960, 965

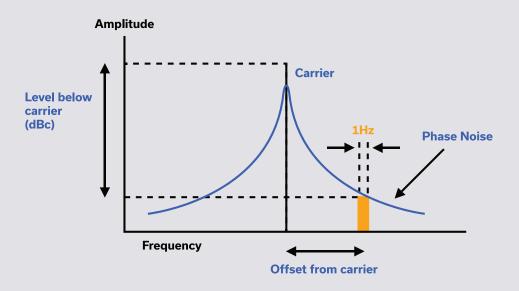




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Adapting Counter-UAV Systems to the Environment

Tobias Willuhn

Rohde & Schwarz, Munich, Germany

nmanned aerial vehicles (UAV) or drones are now integral to our lives. They provide filmmakers with spectacular images and deliver urgently needed medicines to remote areas. Yet, when misused, they can cause damage in the millions. This has driven the demand for highly effective and reliable drone defense systems. These popular unmanned aircraft cost a few hundred euros in online shops, hardware stores and tov stores and, in just a few years, have become a serious hazard worldwide. While there are strict limitations on the commercial use of unmanned aerial systems or drones, it does not stop amateur video makers, curious spectators, industrial spies and other electronic-savvy criminals. A drone can critically disrupt air traffic. In U.S. airspace alone, the Federal Aviation Administration receives more than 100 reports of drone incidents each month. Mountain rescue helicopter flights have been canceled due to quadcopters zooming around in the vicinity. A drone filmed a car manufacturer's latest model during a secret drive for a commercial. Rugged homemade aerial devices have delivered drugs and weapons inside prisons and have even been used as remotely controlled weapons.

DETECTING AND DISABLING DRONES

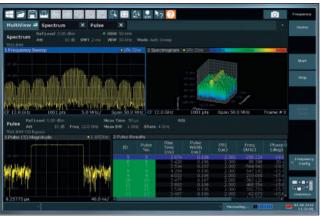
Protective measures against drones can only be taken after the drone is detected. To effectively counter the

threat, early warning is critical. Most commercial counter unmanned aerial vehicle (CUAV) systems can block the radio link between the remote control transmitter and the drone receiver to prevent the aerial vehicle from penetrating a no-fly zone; to do so, they must disable the radio communication. As the ISM bands are full of signals, the challenge is finding the right one. Enhanced CUAV technology can detect commercial drone activity and automatically classify the type of drone signal. It can determine the direction of the drone, its pilot and, on command, disrupt the radio control link to prevent the drone from reaching its target.

Most commercial drones are controlled with an uplink signal from the remote control to the drone using fre-

quency hopping spread spectrum (FHSS). Another family of drones uses the WLAN standard for control. Signals transmitted to the ground from the drones (i.e., the downlink) are typically FHSS, wideband or WLAN signals. To detect the drone's radiocommunications (RC) signals, highly sensitive antennas and monitoring receivers are conditions—Fresnel- analyzer. free zone, low noise environment and CE-conforming transmitters—commercial off-the-shelf RCs can be detected up to 7 km and 5 km for drones such as the DJI Phantom 4.

Some CUAV systems use radars sensors for detection; these require line-of-sight (LOS) to the drone. Other sensors, such as acoustic, are limited by range and environmental factors. Monitoring the RC links is the only method which enables a drone to be detected the moment it is switched on. RC activity can be recognized even before a drone takes off, as drones require preflight checks. During this time, the RC is active and can be detected. With this early warning, CUAV systems using RC monitoring provide a key advantage to any multi-sensor CUAV sys-



needed. Under ideal A Fig. 1 Analyzing a radar pulse using an R&S spectrum conditions—Fresnel- analyzer.







TECHNICAL FEATURE

tem—more time to react. Also, determining the drone pilot's location from the RC signal enables security personnel to deploy quickly, with a greater chance of finding and apprehending the pilot.

DRONE DETECTION RADAR

Because of a drone's small size, low altitude and slow speed, reliably detecting it is a challenge for radar. Radar sensors must quickly scan large volumes with great sensitivity, eliminate nuisance alarms such as birds and reliably discriminate UAVs from ground targets (see *Figure 1*). When designing a drone detection radar, the key design considerations are:

- Radar operating frequency
- Scan coverage and response time
- Resolution and environmental considerations
- Classification capability.

The operating frequency is determined by considering propagation efficiency, the scanned terrain and environment, desired detection range and minimum detectable radar cross section. With many applications requiring 360-degree azimuth coverage, the scanning

requirements range from monitoring large spatial volumes with high refresh rates to illuminating contacts to classify and initiate countermeasures. Further classification using secondary sensors such as optical or audio requires accurate information regarding range, bearing and height, which often demands complex 3D capabilities. To determine the performance requirements for the component, module or subsystem, the appropriate solutions should cover all relevant measurements for power output, antenna pattern, spectral emission mask, interface performance and the phase noise of phased-locked loops in the microwave signal generator.

DETECTING DRONES USING RC

To detect FHSS-controlled drones using their RC signals, the CUAV system should compare measured signals with a library of drone profiles. With automatic online hopper analysis, the system can identify signal parameters such as hop length, symbol rate and modulation type, which enables classifying the drone. With this, the CUAV system can force the drone to safely fail by disrupting the control signal with

a "smart," adaptive, low-power countermeasure. A wideband smart exciter can selectively jam only the detected FHSS signals and disrupt the drone's uplink. With WLAN-controlled drones, an RC-based CUAV system using sectorial WLAN antennas for directional information can disrupt the WLAN link between the remote control and the drone.

Other CUAV solutions use a barrage jammer, which spreads power over the complete frequency band. This requires high output power and disrupts all active transmissions in the frequency band, not only the control signal for the drone.

In addition to detecting and jamming the drone, the CUAV system should provide direction finding information: the direction of the operator from the direction of the RC uplink signal and the direction of the drone from the direction of the telemetry or video downlink signal.

DETECTION AND JAMMING RANGES

For drone detection, the received RC signal strength at the CUAV receiver must be equal to or greater than the receiver (Rx) sensitivity or minimum signal-to-noise ratio (SNR), i.e., the minimum level for drone detection. The SNR depends on the actual RF environment and changes continuously. A cluttered RF environment, for example, will reduce the detection range. To classify the drone type, a minimum Rx level must be received by the CUAV receiver. This minimum level is specific to the type of drone and depends on the FHSS modulation of the RC signal and the overall noise perceived by the detector. Figure 2 illustrates the maximum detection range in an environment with minimal noise. In an electromagnetically noisy environment such as a city, the detection range is substantially reduced (see Figure 3).

A drone is controllable when the RC signal strength at the drone receiver is greater than the minimum Rx level. If a jamming signal is also present and greater than the RC signal power at the drone—when the jamming-to-signal ratio (JSR) is \geq 0 dB—the drone is typically no longer controllable by the pilot, although this depends on the coding scheme of the remote control (see *Figure 4*). The greater the JSR, the higher the probability the CUAV can disable

Figure 5 illustrates a jamming test using a CE-compliant remote-con-



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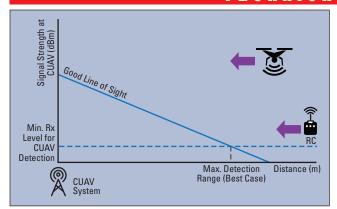


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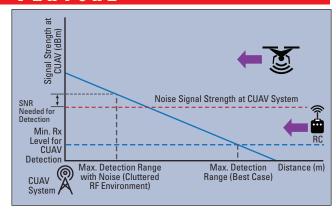
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★ Fig. 2 Theoretical detection range without noise.

trolled drone with the uplink in the 2.4 GHz band. The jammer uses a power amplifier connected to a Rohde & Schwarz UHF omnidirectional antenna with a 10 m cable. Three types of jamming signals were evaluated: barrage jamming, smart jamming without a time raster detector and smart jamming with a time raster detector. The plot shows the jamming ratio versus amplifier output power for the three scenarios, showing smart jamming is more effective than barrage jamming.

Marketing the effectiveness of their systems, CUAV manufacturers often claim long ranges and precise jamming distances; however, these figures are not precise. The jamming range will depend on the ratio of the jammer signal strength to the RC uplink signal strength at the drone, i.e.,



▲ Fig. 3 Theoretical detection range with noise, e.g., in an urban environment.

the JSR. Under realistic conditions, field trials have repeatedly shown the range claims of CUAV system suppliers are often not verifiable. Ironically, the performance of systems claiming relatively short ranges, such as 2 km, is often similar to systems claiming longer ranges, such as 15 km. What is a realistic detection range? In some scenarios, systems will achieve very long detection ranges, which are usually the values shown in the technical specifications of CUAV systems. Yet these "best case" circumstances do not represent the performance in typical rural or urban deployments. Environmental conditions, such as RF noise or the relative permittivity of the ground influence detection and jamming ranges. The environment changes constantly, and the measured de-





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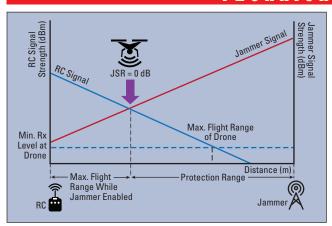
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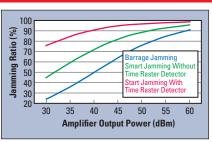
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★ Fig. 4 Theoretical jamming range.

tection and jamming ranges will often vary with every measurement.

To achieve exceptionally long detection ranges, the Rx antenna of the CUAV system should be elevated, and the terrain between the CUAV Rx antenna and the RCTx antenna should have low relative permittivity, such as a freshwater lake at 0°C water temperature. The first, second and third Fresnel zones should be free of obstacles, and the RF environment should have low noise—thermal and from other transmitters. The RC signal frequency should be in a low frequency band, the signal should have high output power and the antenna cables should be short. Choosing antennas with higher directionality will increase the antenna gain.



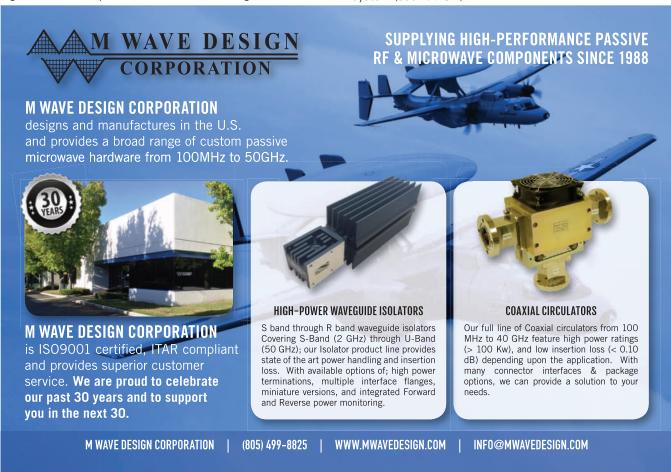
▲ Fig. 5 Jamming ratio for CEcompliant remote control operating in the 2.4 GHz ISM band.

DEPLOYING CUAV SYSTEMS

As CUAV systems depend on the application environment, they must be adapted to each scenario to achieve the optimum detection and jamming ranges. The distance ranges published by manufacturers only

gives an indication of how to optimize the CUAV system for the application.

Under optimized conditions, the R&S ARDRONIS CUAV system can detect an RC signal out to 7 km. Detection ranges measured in urban or rural environments are shorter because of lower SNR, non-optimized antenna sites and other factors. *Table 1* shows several environments and the typical ranges the ARDRONIS system can detect a CE-compliant RC output signal at 2.4 GHz, comparing urban, rural and low noise environments with LOS and non-LOS between the drone and CUAV. The R&S ARDRONIS system uses a wideband smart exciter for jamming remote-controlled transmission, using a FHSS signal matching the signal of the detected type of drone. Its jamming range will depend on the output power of the remote control and the detection range of the system (see *Table 2*).



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TABLE 1

TYPICAL DETECTION RANGES (CE-COMPLIANT OUTPUT POWER AT 2.4 GHz)

Environment	Range (km)	
Urban, LOS	0.2–0.8	
Urban, NLOS	≤ 0.1	
Rural, LOS	1.0–1.5	
Rural, NLOS	≤ 0.4	
Low Radio Noise, LOS	4–7	
Low Radio Noise, NLOS	≤ 0.5	

Determining what detection and jamming ranges are acceptable for a specific application depends on the following considerations:

- What time is needed from detection to reaction? The earlier a drone is detected, the more time for reaction
- After detecting a drone, what action is required? Activating a jammer is very fast. However, finding and apprehending the pilot with security personnel will take more time.

The longer the required early warning time, the more important short detection and jamming become.

TABLE 2

TYPICAL JAMMING RANGE

Remote Control Compliance	Frequency Band	Max Remote Control EIRP (dBm)	Jamming Range (% of Detection Range)	
CE (Europe)	2.4	20	67	
	5.8	14	84	
FCC (U.S.)	2.4	26	50	
	5.8	26	50	
SRCC (China)	2.4	20	67	
	5.8	26	50	

CONCLUSION

All CUAV systems are subject to the laws of physics. Detection range is determined by the relative location of the RC and CUAV system, the Tx power of the RC and the physical and RF environments. The jamming range is determined by the relative location of the drone and CUAV system, the Tx power of the jammer and, again, the environment. The required detection and jamming ranges depend on the application scenario for the CUAV system. Proper planning for each scenario is necessary before the CUAV system can be defined and deployed.

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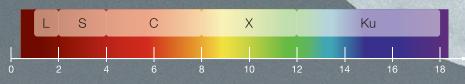


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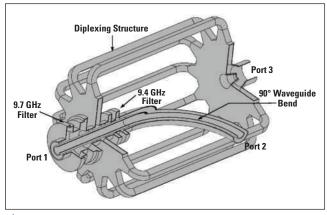
GW, Multi-Way Combiner Using Corrugated Coaxial Waveguide Filters

Xuhao Zhao, Yongjun Hu, Qiang Zhang, Chengwei Yuan and Jiande Zhang

National University of Defense Technology, China

A high-power, low loss radial waveguide combiner design was based on two bandpass filters and two radial waveguide structures connected by 12 rectangular waveguides. The transverse electromagnetic (TEM) mode coaxial waveguide filters had greater than 99 percent transmission efficiency across the 300 MHz bandwidth. Long pulse power combining measurements at 9.38 and 9.7 GHz demonstrated gigawatt (GW) power handling capacity and high transmission efficiency.

igh-power microwave (HPM) has emerged in recent years with new applications and innovative ways to approach existing applications in areas such as directedenergy weapons, plasma heating, atmospheric



▲ Fig. 1 High-power combiner.

monitoring and space.¹⁻⁴ Narrowband HPM devices have been widely developed and GW level outputs have been achieved experimentally.^{5,6} Owing to the limitation of physics and technologies, however, further improvement in the output power capability of a single HPM source has encountered bottlenecks.^{7,8} To overcome this, an effective approach to obtain higher output power is using waveguide power combining technologies. 9-11 Based on polarization orientation of the combined microwaves, these technologies can be divided into cross-polarization synthesis and co-polarization synthesis. For cross-polarization synthesis, a T-junction combiner with two kinds of metal plates and a cross-junction combiner have been verified by simulation and experiment.^{9,10} For co-polarization synthesis, multiplexers based on waveguide filters have been widely adopted.

An S-Band multiplexer with three rectangular waveguide filters was described by Li et al. ¹¹ Within a 100 MHz passband, the energy ef-



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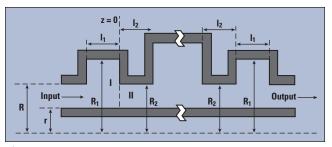


Fig. 2 Azimuthally symmetric coaxial filter structure.

ficiency of the diplexer was as high as 95 percent. With 1 GW of incident microwave power, however, the maximum electric field (E-field) of the entire device exceeded 500 kV/cm, causing E-field breakdown. It also suffered from issues such as large size, dispersion and diffraction. In this work, a high-power, radial waveguide X-Band combiner was designed using two radial waveguide structures and two wideband filters. Its transmission characteristics were investigated through theoretical analysis and simulation. Long pulse measurements were conducted without microwave breakdown. Experimental results agreed with the analysis, which indicates a transmission efficiency greater than 95 percent within the 300 MHz passband, with power handling greater than 1.5 GW.

DESIGN AND SIMULATION

The combiner consists of six parts (see *Figure 1*): 9.4 GHz waveguide filter, 90-degree coaxial waveguide bend, 9.7 GHz waveguide filter, branching structure, multi-way transmission structure and combining structure. The 9.7 GHz TEM microwave signal travels through the 9.7 GHz filter and is reflected by the 9.4 GHz filter, forming standing waves. Taking advantage of magnetic coupling in the branching structure with 12 rectangular waveguide ports, the standing waves are extracted and propagate through the 12-path transmission structure. Outputs from the 12 paths are added in the combining structure. The 9.4 GHz signal is input into the combiner via a 90-degree bend and is similarly processed.

The performance of the bandpass filters determines the device threshold. Therefore, an azimuthally symmetric coaxial filter structure is used to realize high-power and low loss (see *Figure 2*). It can be regarded as multiple step discontinuities isolated by short coaxial waveguides. Mode matching theory was used to analyze the step discontinuities in the coaxial waveguide to obtain the structure's scattering matrix. $^{12,\,13}$ Based on mode matching theory, only the TEM and TM_{0m} mode can be excited when the TEM mode is injected. The mode matching coefficients at the junction (z = 0) are shown by Equations 1 through 3, respectively.

$$I: TEM \to II: TM_{0n} \tag{1}$$

$$P_1 = 2(A_1 - A_6)$$

$$\sqrt{\frac{60\pi\omega\varepsilon}{\beta_{0n}^{II}((v_{0n}^{II})^2A_2^2 - (\frac{rv_{0n}^{II}}{R_2})^2A_3^2(\ln R_1 - \ln r)}}$$

$$I: TM_{0m} \rightarrow II: TEM$$

$$P_2 = 0$$
 (2)

$$I: TM_{0m} \rightarrow II: TM_{0n}$$

$$P_{3} = -2\frac{\chi_{0n}^{2} ^{\parallel} v_{0m}^{l} (A_{4} A_{1} - \frac{r}{R_{1}} A_{6} A_{5})}{v_{0n}^{\parallel} v_{0m}^{l} (\chi_{0m}^{2} - \chi_{0n}^{2} ^{\parallel})}$$

$$\sqrt{\frac{\beta_{0m}^{l}}{\beta_{0n}^{l}[A_{2}^{2} - (\frac{r}{R_{2}})^{2}A_{3}^{2}][A_{1}^{2} - (\frac{r}{R_{1}})^{2}A_{5}^{2}]}}$$
(3)

where β^i_{0p} is the propagation constant of TM_{0p} mode in region i, ν^i_{0p} is the pth root of Equation 4, with κ^i_{0p} the cutoff wave number of the TM_{0p} mode in region i. Ai is shown in Equation 5:

$$J_{0}(v_{0p}r/R)N_{0}(v_{0p})-N_{0}$$

$$(v_{0p}r/R)J_{0}(v_{0p})=0$$
(4)

$$\begin{split} &A_{1} = J_{0}(v_{0m}^{l})N_{1}(v_{0m}^{l}) - J_{1}(v_{0m}^{l})N_{0}(v_{0m}^{l}) \\ &A_{2} = J_{0}(v_{0n}^{ll})N_{1}(v_{0n}^{ll}) - J_{1}(v_{0n}^{ll})N_{0}(v_{0n}^{ll}) \\ &A_{3} = J_{0}(v_{0n}^{ll})N_{1}(\frac{rv_{0n}^{ll}}{R_{2}}) - J_{1}(\frac{rv_{0n}^{ll}}{R_{2}})N_{0}(v_{0n}^{ll}) \\ &A_{4} = J_{0}(\frac{R_{1}v_{0n}^{ll}}{R_{2}})N_{0}(v_{0n}^{ll}) - J_{0}(v_{0n}^{ll})N_{0}(\frac{R_{1}v_{0n}^{ll}}{R_{2}}) \\ &A_{5} = J_{0}(v_{0m}^{l})N_{1}(\frac{rv_{0m}^{l}}{R_{1}}) - J_{1}(\frac{rv_{0m}^{l}}{R_{1}})N_{0}(v_{0m}^{l}) \\ &A_{6} = J_{0}(\frac{rv_{0n}^{ll}}{R_{2}})N_{0}(v_{0n}^{ll}) - J_{0}(v_{0n}^{ll})N_{0}(\frac{rv_{0n}^{ll}}{R_{2}}) \end{split}$$
 (5)

Corrugated coaxial waveguide filters with 9.4 and 9.7 GHz center frequencies, respectively, were designed based on the above analysis. The total lengths of both filters are less than 180 mm. To ensure the TM_{0m} mode degenerates in the radial waveguide, the radius of the input and output ports of the filters were set at 75 and 72.7 mm, respectively, with the radius of the inner cores at 60 and 58.1 mm. The dimensions of the coaxial waveguide filter parameters are listed in

The entire combiner was simulated with the branching and combining structure and 90-degree coaxial waveguide bend

TABLE 1 FILTER PARAMETERS (MM) 9.4 GHz 9.7 GHz R 75 72.7 58.1 60 R. 115.8 96.8 I, 32.7 29.9 R. 112.8 69.5 24 32.8 1 R, 84.5 45.2

(see Figure 3). The simulation shows the transmission efficiencies of the TEM mode from port 1 to 3 and port 2 to 3 are both over 98 percent within the MHz passband. The bandwidth is broad for enough narrowband HPM sources. The transmission characteristics of the combiner also verify the high





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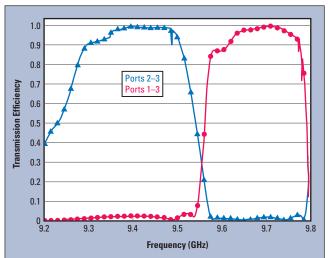


Fig. 3 Simulated combiner frequency response.

transmission efficiency and high isolation of the two filter designs. Since propagation is by traveling waves within the filters and standing waves within the other parts of the combiner, the maximum E-field occurs inside the corresponding filters when transmitting the 9.4 and 9.7 GHz signals, respectively. Simulated E-field distributions in the 9.4 GHz coaxial waveguide filter are shown in *Figures 4a* and *b*. The input wave is reflected at 9.7 GHz and passed at 9.4 GHz. E-field distributions of the 9.7 GHz coaxial waveguide filter are shown in *Figures 5a* and *b*. Here, the input wave is reflected at 9.4 GHz and passed at 9.7 GHz. The 9.7 GHz signal propagates through the 9.7 GHz filter and is reflected by the 9.4 GHz filter, which forms standing waves to be extracted. The mechanism at 9.4 GHz works in a likewise manner.

The input and output modes of the filters are both TEM. With both ports 1 and 2 fed by a 1.0 GW microwave input, the maximum E-fields inside the 9.4 and 9.7 GHz filters were calculated to be 198.64 and 302.16 kV/cm, respectively. It is noteworthy that the E-field enhancement occurring at the corner of the step discontinuities of both filters is less

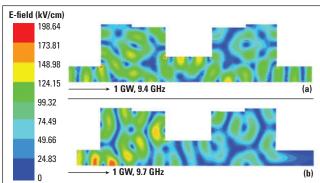
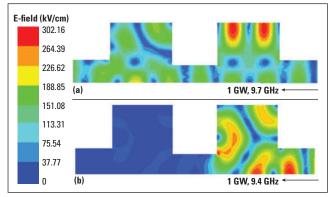


Fig. 4 Simulated 9.4 GHz filter E-field distributions for 9.4 (a) and 9.7 (b) GHz.



▲ Fig. 5 Simulated 9.7 GHz filter E-field distributions for 9.7 (a) and 9.4 (b) GHz.

than 200 kV/cm, not high enough to affect the transmission characteristic. Generally, the combiner is pumped to a high vacuum state for the HPM application, in which the E-field breakdown threshold is greater than 500 kV/cm. According to Equation 6, the combiner can realize the power combining of several GWs.

$$P_{\text{max}} = \left(E_{\text{max}}/E_{\text{input-max}}\right)^2 \times P_{\text{input}}$$
 (6)

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MEASUREMENTS

To verify the simulated performance and power handling, the combiner shown in Figure 6 was fabricated and tested, using a 9.38 GHz. 100 ns relativistic backward wave oscillator (RBWO) and a 9.7 GHz, 9 ns RBWO as sources. The input powers were 1.78 and 1.5 GW, respectively. 14 The test layout is shown in Figure 7. To ensure accuracy, two angles, 14 and

🖊 Fig. 6 Fabricated high-power coaxial waveguide combiner.

20 degrees, were chosen to measure the output power.

Figure 8 shows the output waveforms at 9.38 and 9.7 GHz with pulse durations and 95 measured at 14 degrees. The blue waveforms represent the far-field

measurements of the 9.38 and 9.7 GHz RBWOs, respectively. The green waveforms represent the inline measurements used to monitor the working condition of the HPM source. Measurement of the radiation field was done with the same diode voltage and beam current to acquire the power handling capacity and transmission efficiency. With long pulses, the average power levels detected by antennas 1 and 2 were 1.7 and 1.43 GW, respectively. From this, the insertion loss of the combiner was calculated to be 4.5 percent and the transmission

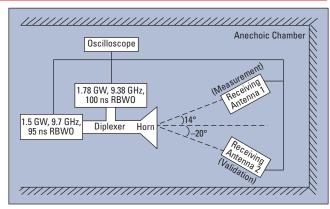


Fig. 7 Test setup.

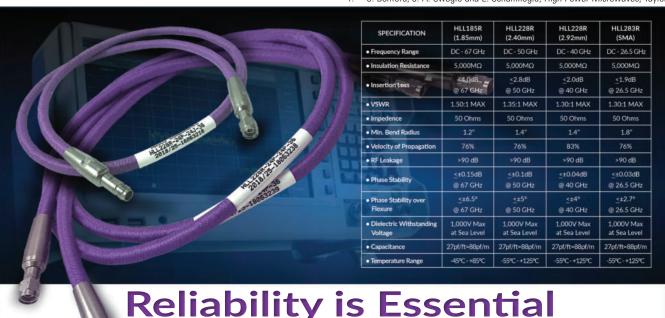
efficiency about 95.5 percent. No microwave breakdown or pulse shortening phenomena were observed during testing.

CONCLUSION

A multi-way waveguide structure featuring high-power handling with low loss combined 9.38 and 9.7 GHz HPM sources. No breakdown or pulse shortening phenomenon was detected with 100 ns, 1.78 GW and 95 ns, 1.5 GW pulses, respectively. The transmission efficiency was greater than 95.5 percent within the ±150 MHz passband.

References

J. Benford, J. A. Swegle and E. Schamiloglu, High Power Microwaves, Taylor



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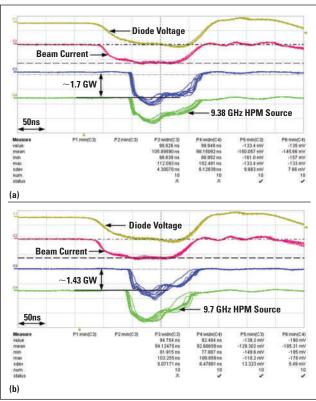


Fig. 8 Output waveforms at 9.38 (a) and 9.7 (b) GHz.

& Francis, New York, 2007, 2nd edition.

- R. J. Barker and E. Schamiloglu, High-Power Microwave Sources and Technologies, IEEE Press, New York, NY, 2001.
- A. P. Smirnov, N. V. Suetin and A. B. Shmelev, "Two-Dimensional Bounce-Averaged Fokker-Planck Modelling of an Electron Cyclotron Resonance Plasma Source," *Journal of Plasma Physics*, Vol. 59, No. 2, February 1998, pp. 243

 257.
- J. Benford, "Space Applications of High-Power Microwaves," IEEE Transactions on Plasma Science, Vol. 36, No. 3, June 2008, pp. 569–581.
- J. T. He, H. -H. Zhong and Y. G. Liu, "A New Low-Impedance High Power Microwave Source," *Chinese Physics Letters*, Vol. 21, No. 6, June 2004, pp. 1111–1113.
- D. Wang, F. Qin, D. B. Chen, J. Wen and X. Jin, "X Band Bifrequency Coaxial Relativistic Backward Wave Oscillator," AIP Advances, Vol. 1, No. 4, November 2011.
- Z. Jin, J. Zhang, J. Yang, H. Zhong, B. Qian, T. Shu, J. Zhang, S. Zhou and L. Xu, "A Repetitive S-Band Long-Pulse Relativistic Backward-Wave Oscillator," Review of Scientific Instruments, Vol. 82, No. 8, August 2011.
- 8. J. Zhang, H. H. Zhong and L. Luo, "A Novel Overmoded Slow-Wave High-Power Microwave (HPM) Generator," *IEEE Transactions on Plasma Science*, Vol. 32, No. 6, December 2004, pp. 2236–2242.
- Q. Zhang, C, Yuan and L. Liu, "T-Junction Waveguide-Based Combining High Power Microwave Beams," *Physics of Plasmas*, Vol. 18, No. 8, August 2011.
- Q. Zhang, S. Peng, C. Yuan and L. Liu, "Waveguide-Based Combining S-Band High Power Microwaves," *IET Microwaves, Antennas & Propagation*, Vol. 8, No. 10, July 2014, pp. 770–774.
- G. -L Li, T. Shu and C. W. Yuan, "Output Multiplexer for S Band High Power Microwave," High Power Laser & Particle Beams, Vol. 19, No. 4, April 2007, pp. 667–670.
- G. L. James and B. M. Thomas, "TE /sub 11/ to HE /sub11/ Cylindrical Waveguide Mode Converters Using Ring-Loaded Slots," *IEEE Transactions on Micro*wave Theory & Techniques, Vol. 30, No. 3, March 1982, pp. 278–285.
- C. Y. Fang, J. S. Gao and H. Liu, "A Novel Metamaterial Filter with Stable Passband Performance Based on Frequency Selective Surface," AIP Advances, Vol. 4, No. 7, July 2014.
- J. Zhang, Z. Jin, J. Yang and H. Zhong, "Design and Experiment of X-Band Long-Pulse High Power Microwave Source," *High Power Laser & Particle Beams*, Vol. 22, No. 11, November 2010, pp. 2643

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Software-Defined Radio: High Performance, Flexible Technology for Spectrum Monitoring

Reza Mohammadi and Simon Ndiritu

Per Vices, Toronto, Canada

The software-defined radio (SDR) paradigm replaces hardware with flexible software-based components that are inexpensive and easily upgraded to meet current and future needs in spectrum management.

he radio spectrum is used for a wide range of radio services, including mobile phone communications, police and other emergency communications, radar and satellite services, broadcast radio and television. To ensure equitable, economical and efficient use of this scarce resource, government regulatory authorities allocate frequencies for different radio communication services and assign specific frequencies to users. Since it is important for users to operate strictly within their allocated frequency bands, regulators employ various techniques to monitor and record spectrum use.

Spectrum monitoring and recording are critical components of spectrum management. Spectrum monitoring enables spectrum regulators to plan frequency use, avoid incompatible use of

frequencies and identify sources of unwanted electromagnetic emissions that may impair the services provided by licensed spectrum users. This involves measuring various performance parameters and analyzing the data to ensure users are complying with regulatory requirements. Measurements monitor spectrum occupancy, occupancy rates and scan frequency bands to identify unknown transmitters. In locations where the RF spectrum is crowded, monitoring and recording systems capture large amounts of data. Spectrum monitoring stations in these areas require high performance monitoring and recording equipment. Such sophisticated, hardware-based instruments are traditionally expensive and designed for single-use applications.

As the number of parameters and services



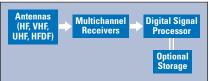


Fig. 1 Spectrum monitoring and recording system.

increase, so does the demand for more flexible and higher performance measurements and instruments to make them. A spectrum monitoring and recording system typically consists of an antenna system, a high performance radio receiver, a data storage unit and a signal processing unit (see *Figure 1*); the signal processing may be incorporated into the radio or data storage unit.

BENEFITS OF SDR SPECTRUM MONITORING

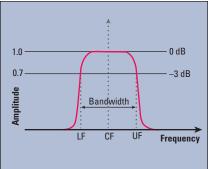
As noted, spectrum monitoring and recording applications demand flexible, high performance solutions. Traditional spectrum monitoring instruments are based on dedicated hardware components, typically expensive and difficult to upgrade for new applications. So they quickly become obsolete.

The SDR paradigm replaces hardware components with flexible and inexpensive software-based components, which are easily upgraded. These software-based components include modulators, demodulators, mixers, filters and amplifiers and since system upgrades require no hardware modification, SDR technology is more suited for rapidly changing spectrum monitoring applications.

Traditional spectrum monitoring systems using only dedicated hardware components greatly limits performance. However, a SDR system can achieve wideband operation, high channel count and wide bandwidths. SDR technology also reduces the cost to produce high performance RF instruments while reducing development time.

SDR PARAMETERS Probability of Intercept

Probability of intercept (POI) is a measure of the minimum duration a signal is required to be detectable for an instrument to intercept it with 100 percent probability. It is usually specified in milliseconds, microseconds or nanoseconds. When a monitoring system is described as a high POI instrument, it means the device requires a shorter signal duration for 100 percent POI; a



▲ Fig. 2 Communications channel bandwidth.

low POI monitoring system requires a longer signal duration. Using a high POI instrument increases the probability of capturing the signal of interest.

Most traditional hardware spectrum monitoring and recording instruments scan for unwanted signals by sweeping from low to high frequencies. This technique yields a low POI and makes these instruments unsuited for capturing short duration signals. Modern SDR instruments are capable of continuously measuring the spectrum for frequencies within their specified spans. This technique yields a higher POI and can capture very short duration signals.

Bandwidth

Radio systems are generally categorized by their bandwidth (see *Figure 2*), i.e., narrowband or wideband. Systems that can tune a large portion of spectrum are referred to as wideband and are commonly used for video streaming, surveillance systems and other applications that need wide bandwidth to carry high data rates. In addition to bandwidth, wideband spectrum monitoring applications require instruments capable of acquiring, storing and processing large volumes of data.

One of the key digital features of a modern SDR spectrum monitoring system is the digital signal processor, which are typically implemented in FPGAs or ASICs. Using reconfigurable devices, such as FPGAs, provide flexibility for upgrades to maintain the longevity of the system, by enabling new features to be deployed in software, rather than requiring new hardware.

Data Capture

Spectrum monitoring and recording instruments capture large amounts of data, especially in locations where the spectral environment is crowded; however, most of the processing is not done in real-time on the radio. The



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▲ Fig. 3 High performance RF stream-to-disk system.

captured data is usually transferred to a storage bank for processing and analysis later. In most spectrum monitoring instruments, transferring captured data to the storage unit uses traditional data buses and protocols, even though traditional standards are highly susceptible to packet losses, meaning some critical data is lost. New and emerging interfaces such as 10G, 40G and 100G Ethernet have high speed with data integrity, making them suitable for high performance spectrum monitoring and recording instruments.

A broad array of analysis methods and techniques are used to characterize signals of interest. The Gabor spectrogram, for example, is commonly used to observe changes in the frequency, amplitude and duration of a signal to identify sources of interference. To employ advanced analysis techniques, such as modulation analysis and the Gabor spectrogram, rich datasets of waveforms acquired over long periods of time are required. Traditional spectrum monitoring solutions typically lack the throughput to transfer large amounts of high bandwidth data to storage, and these limitations make them incapable of continuously storing waveforms acquired over long durations.

Data Transfer

For most RF systems, data storage is determined by many factors, including the digital interface between the radio and the storage solution, the network interface controller (NIC), the random access memory (RAM) and the hard drive interfaces and configuration. A system that can store the high bandwidth data acquired by current radio receivers requires a digital backhaul that supports high speed data transfer, linking the radio to the storage. 40G and 100G links are the best choices to meet the high speed data transmission requirements.

The maximum data transfer rate is also determined by the NIC. Unlike traditional network interface controllers, today's devices are engineered to support high speed data transfer. The rate data is written to storage depends on the RAM. High performance RAM is required, which also affects the reliability of the data transfer.

Data Storage

To store the streamed data, storage based on redundant array of independent disks (RAID) technology or enterprise grade hard drives is required. RAID virtualization technology delivers high storage performance with multiple ways to configure the hard drives: RAID 0, RAID 1, RAID 5 and RAID 10. RAID 0 provides excellent performance, RAID 1 has excellent redundancy and the RAID 10 configuration combines the performance characteristics of RAID 0 and RAID 1. RAID 10 is, therefore, the best choice for achieving performance and redundancy. Of course, the hard drive interfaces must be capable of supporting high speed data transfer.

By combining high performance RAM, a high speed data bus, a high speed NIC and the latest hard drive technology, a high performance stream-to-disk solution capable of storing several terabytes of data can be achieved (see *Figure 3*). Considering the spectrum monitoring challenges posed by today's crowded spectral environments, the capability to continuously stream data to a storage solution for a long duration offers significant benefits to spectrum managers and users.

SUMMARY

The factors to consider when choosing an SDR solution include frequency of operation, number of independent channels, RF bandwidth, digital backhaul and the availability of pre-configured storage and playback options. The solution must be flexible and adaptable to accommodate new and emerging technologies, including the ability to tune into desired frequency bands and adjust the bandwidth to suit the application. Having multiple channels enables data to be captured at different frequencies or time intervals. Connecting a radio and a recording and playback system for spectrum monitoring can be daunting. To avoid implementation delays and performance issues—dropped packets or configuration challengesworking with a company offering a complete solution can reduce the time to implement a system and minimize risks to the project.

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Satcom: The New mmWave Frontier

Nancy Friedrich

Keysight Technologies, Santa Rosa, Calif.

While space will push the boundaries of mmWave technology and communications, success depends on overcoming the challenges arising from the process.

n our spectrum-constrained world, the idea of going to higher frequencies, where spectrum is available, seems like a dream come true. For wireless systems ranging from 5G through satellite communications (satcom), mmWave offers that much-desired spectrum. For satcom, moving to mmWave promises advantages ranging from higher data throughput to finer range resolution from ultra-wide bandwidth. Of course, technology evolution always reveals new challenges. In space and satellite applications, these challenges are compounded by the pressure to drive down cost while accelerating design and manufacturing. As satellite systems add capabilities and reach new levels of performance, more uncertainty arises. Designers must pinpoint potential problems, verifying issues before launch to assure mission success.

Much of today's mmWave focus is on 5G non-terrestrial networks (NTNs). Yet planning already has begun for 6G cellular. 6G satcom

fic while ensuring the performance needed for emerging applications. Success will rely on the use of mmWave frequencies, most likely combining terrestrial and NTN. As the industry builds on 5G NTN networks, it is already outlining the requirements and challenges for 6G. 6G success depends on first overcoming the challenges presented by moving to mmWave with the current satcom and 5G systems.

Wireless technologies increase signal band-

is predicted to meet the future surge in traf-

Wireless technologies increase signal bandwidth and use higher-order modulation to achieve greater data rates. Wider bandwidth is an attractive feature of mmWave communications, presenting opportunities for improved performance; however, wider bandwidth and higher-order modulation introduce challenges related to link quality at mmWave frequencies.

One major issue is the path loss a signal experiences when traveling through a medium like the atmosphere or a cable in the lab. Also, wide bandwidth devices are often difficult to implement and test in a system. The signal-to-noise ratio (SNR) may be lower, there may be more distortion and system components must have tighter margins. These contribute to the difficulty of getting a signal with high fidelity or accuracy.



▲ Fig. 1 OTA test chambers are needed to test highly integrated mmWave components, which often lack physical connections.

TEST CHALLENGES

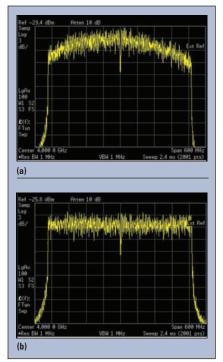
For satellites, the ability to verify and predict real-world performance as accurately as possible is critical for ensuring mission success. The challenges impacting mmWave links also affect test capabilities. For example, excessive path loss between instruments and the devices under test (DUTs) results in a lower SNR, making signal analysis measurements challenging, such as error vector magnitude (EVM), adjacent channel

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power and spurious emissions. Complicating the measurement task, mmWave components are compact and highly integrated with no place to probe, requiring radiated or over-the-air (OTA) tests in an anechoic chamber (see *Figure 1*). With OTA testing, signal levels decrease dramatically, requiring that the test environment be designed and controlled. Path loss also complicates testing. At mmWave frequencies, RF power is limited and expensive, so measuring performance metrics using OTA test methods may limit the ability to achieve accurate and repeatable results.

The mmWave frequency bands offer wide bandwidths, which enable high throughput data, range resolution, accuracy and low latency. Yet they introduce more noise and increase test complexity and measurement uncertainty. Increasing the analysis bandwidth in a signal analyzer raises the noise floor, which reduces the measurement SNR. A low transmit signal may be masked by the noise floor within the channel, requiring better sensitivity at the receiver. These trade-offs make accurate mmWave measurements more challenging.

The frequency response of the overall system must also be considered. A test system's primary objective is to characterize a DUT; the test system must isolate the DUT from all other test effects. The components between a



▲ Fig. 2 Poor (a) vs. flat (b) spectrum of an OFDM modulated signal.

signal analyzer and the DUT—mixers, filters and amplifiers—contribute to the overall frequency response of the measurement. The individual frequency responses contribute amplitude and phase errors which will degrade modulation quality, and these frequency response effects generally get worse when testing signals with wider bandwidths and at higher frequencies (see *Figure 2*).

BETTER MEASUREMENTS

Whether assessing transmitters, troubleshooting receivers or analyzing OTA signals, the flexibility of the signal analyzer's hardware and software can help optimize the test setup. Input signals can range from high-power to noise-level signals, low frequency to THz and CW to complex wideband modulation. To measure this variety of input signals, signal analyzers should





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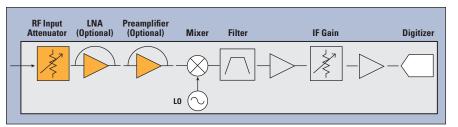
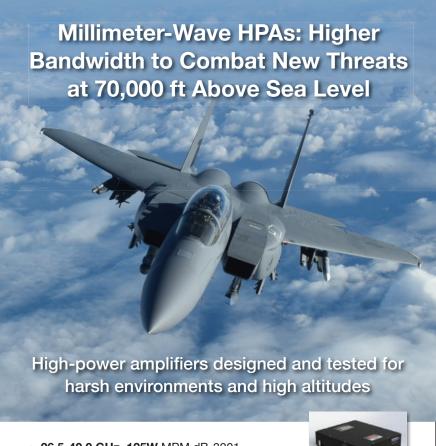


Fig. 3 New signal analyzers help users optimize hardware settings to improve SNR and avoid overloading the digitizer.



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apply attenuation at higher power levels and use a preamplifier to boost lower power signals. Signal analyzers can be designed to provide various signal paths—default, microwave preselector bypass, low noise and a full bypass to lower noise and improve sensitivity or reduce the signal path loss and increase the SNR (see Figure 3).

A signal analyzer with these capabilities offers several methods to mitigate these test challenges and improve measurement results:

Analyzing wideband vector signals — The RF preselector in the signal analyzer most likely has limited bandwidth for image-free analysis. However, the bandwidth limits the RF analysis bandwidth. Bypassing the preselector enables wideband analysis with a flat response over the bandwidth of the digitizer. It improves amplitude accuracy, eliminating amplitude drift and the passband ripple in the preselector and enables wideband signals to be measured, such as 5G, satcom, IEEE 802.11ax/be and radar.

Strong out-of-band signals -When the input signal includes strong out-of-band signals, such as from a mixer with local oscillator (LO) leakage or spurs, the out-of-band signals can cause imaging and in-band interference within the analysis bandwidth, leading to failed measurements. A bandpass filter at the input of the signal analyzer can filter out these unwanted signals.

High power level — For testing transmitter modulation quality at high power, such as EVM, the signal analyzer may be set to a low noise path, which bypasses the preamplifiers and the lossy switches in the preamplifier path. At higher frequencies, the gain of the amplifier will decrease, and the insertion loss of the passive components will increase. A low noise path reduces this loss and eliminates the frequency response and noise from the preamplifiers and switches, improving signal fidelity and measurement sensitivity and yielding better wideband EVM measurement, particularly at higher frequencies.

Lower power levels — When testing at low power levels, such as an OTA setup, an internal or external preamplifier is necessary to increase the SNR for accurate modulation analysis.

Wideband modulation analysis — The full bypass path of a signal analyzer combines the low noise path with the microwave preselector bypass path. This setting eliminates the multiple switches in the low band switch



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circuitry and bypasses the microwave preselector. The full bypass path provides lower path loss, improving signal fidelity and measurement sensitivity. However, it may have disadvantages, such as in-band imaging and low SNR for testing at lower signal levels. Adding a bandpass filter to eliminate images in the measurement band can improve EVM measurements by 1 to 2 dB. Also, adding an external preamplifier can improve the SNR when testing lower power signals.

Insertion loss — In a mmWave test system, the cables and accessories between the signal analyzer and the DUT increase insertion loss. Cable loss can reach 5 dB, which will reduce the SNR of the measurement system. Adding an external mixer is a cost-effective way to extend the frequency range of the signal analyzer and move the mixer closer to the DUT, which shortens the signal routing, reduces loss and improves the SNR.

Production — mmWave test system integration and test costs create higher barriers when moving a project from R&D to volume production. A banded solution is a common approach to high volume production test. For example, an RF vector signal analyzer (VSA) and an RF vector signal generator (VSG) are essential for testing at the lower 5G frequency bands, i.e., FR1. For mmWave testing, i.e., FR2, the VSA and VSG can be used at the intermediate frequency (IF) and coupled with an external mmWave transceiver.

Using an external transceiver, the signal analyzer supplies a microwave LO signal to the external mixer and receives an IF signal from the mixer. The analyzer processes and displays the IF signal with filtering, digitizing and analysis, as it would with an internally mixed signal. New USB "smart mixers" simplify the connection and measurement, as the analyzer can detect the mixer, automatically download the conversion coefficient and monitor drive levels. External mixing provides a cost-effective solution for mmWave signal analysis and enables the test port to be located closer to the DUT. However, with this configuration there is no preselector at the front-end of the mixer, so strong out-of-band signals may create unwanted images in the measurement band and degrade accuracy. Also, if the test frequency is outside the mixer's frequency band, the test signal must be reconnected to the signal analyzer's RF input port or to another mixer covering the band, with the input source

adjusted accordingly. These aspects increase test complexity and may affect measurement uncertainty.

All wireless standards specify that transmitter measurements should be performed at the maximum output power; however, the power at the first mixer of the signal analyzer may have to be attenuated to ensure the input signal does not distort the signal analyzer. With OTA tests and systems with large

insertion loss, the input signal can be lower than optimum for the mixer. In these cases, the signal analyzer can use a built-in preamplifier, which provides better noise figure yet poorer dynamic range between the intermodulation distortion and noise floor. Another option is using an external low noise amplifier at the front-end, with or without the internal preamplifier, to achieve the best input level to the mixer. Setting the



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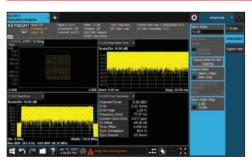


Fig. 4 A built-in LNA reduces noise and two gain stages help balance noise vs. distortion.

put mixer level is a trade-off between distortion performance and noise sensitivity, i.e., achieving better SNR with a higher input mixer level or better distortion performance with a lower input mixer level. The best level depends on the measurement hard-

ware, characteristics of the input signal and specification test requirements.

Optimizing the SNR for the IF digitizer is another consideration. The system IF noise of a signal analyzer must be low enough to get the best EVM measurements, while the input signal to the digitizer must be high enough, yet not overload the digitizer. The optimum setup requires optimizing the combination of RF attenuators, preamplifier and IF gain for the measured peak signal. New signal analyzers have a single key feature which optimizes the hardware settings to maximize the SNR while avoiding digitizer overload (see Figure 4). The optimization process measures the peak signal level, then selects the best settings in the analyzer. Since the optimization period may not see the complete power characteristics of the input signal, the IF gain and RF attenuators can be tweaked manually to fine-



The nature of satellite links creates challenges for RF designers. Beyond assuring communications performance, the system must perform reliably throughout the satellite's life. Once deployed, a satellite cannot be called back for repair. This requires a level of assurance, whether the satellite is in geostationary earth orbit or part of a low earth orbit constellation. To address the challenges from higher frequency and wider bandwidth operation, more complex testing and characterization are needed to ensure the mmWave component and device measurements are accurate and the components and systems meet the demanding space requirements.

As the bandwidths and frequencies increase, the small margin of error allowable for measurements requires new ways to reduce errors. When the test setup includes connecting cables, connectors, switches and fixtures between the signal analyzer and the DUT, the measurement calibration should be extended from the signal analyzer's input port (i.e., reference plane) to the DUT test port (i.e., measurement plane). Signal analyzers can perform internal calibration routines to correct for frequency response variations, providing complex amplitude and phase corrections to compensate. As more systems move to mmWave frequencies and eventually transition from 5G to 6G, mission success will depend on accurate measurements of device and system performance.



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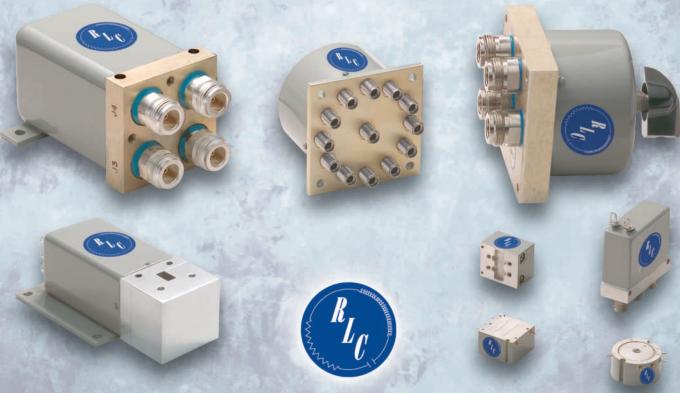
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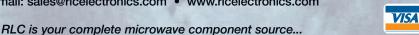


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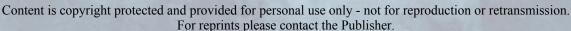
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Fast, Spherical Near-Field Antenna Measurements for Satellites

MVGParis, France

he application of phased-array antennas for LEO constellation satellites is increasing dramatically. To meet the time-to-market demand of this NewSpace sector, the testing, calibration and verification of these antennas must be efficient. Addressing this need, MVG has introduced the SG Evo, a multi-probe spherical near-field antenna measurement solution capable of testing phased-array antennas on high-throughput satellites from 10x to 100x faster than previous near-field test methodologies.

SINGLE- VS. MULTI-PROBE NEAR-FIELD TESTING

When measuring antennas with a single probe near-field system, the probe is positioned in front of each radiating element while the RF is modulated according to the antenna's operating parameters. The accuracy of the probe's position relative to the element is not critical if the probe spacing matches the element spacing and meets the Nyquist sampling criteria. However, probe movement can introduce phase errors caused by RF cable movement, increasing measurement uncertainty. This measurement process is time consuming, since the probe mechanically moves between stop and go, point

by point. For phased-array antennas with many embedded antenna elements, the process may require thousands of measurements and many hours—even days—to complete, with long measurements susceptible to additional errors from temperature fluctuations.

A multi-probe near-field measurement system can perform an electronic 2D scan of a probe array within a few milliseconds and a full 3D spherical radiation pattern in minutes. This saves a tremendous amount of time throughout the cycle of antenna system test and calibration, reducing overall satellite development time.

Like other antennas, phased-array radiation patterns are affected by their environment, so it is important to test the performance when the array is integrated into the final satellite assembly. Measurements of integrated phased-array antennas can interact with the surrounding structure and neighboring antennas. Full system-level testing of the antennas validates their operational connectivity and performance prior to deployment. Testing and calibration of the final payload assembly is a significant step to determine whether a satellite is ready for launch, lowering the risk of a failure in orbit and avoiding the significant costs associated with such a failure (see *Figure 1*).



PRODUCT FEATURE



Fig. 1 Testing an antenna system integrated on a satellite. Source: ESA.



★ Fig. 2 SG Evo multi-probe, spherical, near-field antenna measurement system.

THE SG EVO

To meet the time and accuracy demands of fast-moving LEO satellite development and increased production volumes, MVG developed the SG Evo (see Figure 2). The SG Evo is a multiprobe, spherical, near-field antenna measurement and over-the-air (OTA) test system covering 400 MHz to 30 GHz and measuring between 10x and 100x faster than traditional near-field measurement systems. Designed to provide configuration flexibility, wider frequency range and advanced oversampling capabilities while minimizing the movement of the device under test (DUT), the SG Evo accommodates various device types and sizes. This single antenna measurement system can be used during every stage of system development, from antenna subsystem characterization to system testing with the antennas integrated.

Evolved from MVG's legacy multiprobe antenna measurement systems, the SG Evo delivers fast spherical nearfield measurements with increased measurement accuracy. Using an efficient near-field to far-field transformation and other post-processing capabilities, antennas can be characterized within minutes. Standard measured antenna parameters produced by the SG Evo include gain, directivity, efficiency, radiation patterns, sidelobe levels, beam peak, beamwidth, front-to-back ratio and cross-polarization discrimination (see *Figure 3*).

Comprised of a mechanical arch of multiple wideband, dual linear-polarized probes, the SG Evo performs measurements over a wide frequency range with fast electronic switching of its integrated probe array. An azimuth stage enables easy mounting of DUTs and provides 180-degree rotation, enabling complete 3D spherical pattern characterization. The mechanical arch is designed to provide oversampling, if needed to ac-

commodate measurements at higher frequencies, without repositioning the DUT. This capability increases measurement stability and accuracy by minimizing DUT and cable motion.

The SG Evo also has the capability to perform OTA measurements of subsystems and full system-level DUTs using complex signal modulation. Optimum signal transmission can be measured through total radiated power, total isotro-

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USPA 64 Gbaud Transceiver Design Verification System

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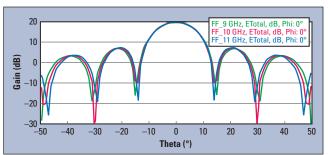
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PRODUCT FEATURE



pic sensitivity, effective isotropic radiated power and effective isotropic sensitivity testing of coordinating satellite antennas in the SG Evo.

Fig. 3 Azimuth radiation pattern.



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OVERSAMPLING

As dictated by the Nyquist sampling criteria, measurement sampling density increases with frequency. For phased-array antenna measurements involving thousands of beam states, hundreds of thousands of samples may be required, and the measurement time can be an issue. These high gain, high frequency space-borne antennas are often sensitive to both movement and temperature, which degrades measurement accuracy. The reduced measurement time and DUT movement afforded by the SG Evo help ensure measurement accuracy.

The SG Evo uses patented technology to perform oversampling and reference measurements. Oversampling is achieved using precision mechanical movement of the probe array. As a result, full 3D device characterization at higher frequencies requires only stepped azimuth rotation of the DUT, which minimizes gravitational deflections and cable motion. The very fast scan speed of the probe array reduces measurement errors caused by temperature change. Incorporating a reference channel into the probe array further compensates for temperature change during 3D measurements. These capabilities of the SG Evo work together to ensure fast and accurate measurements.

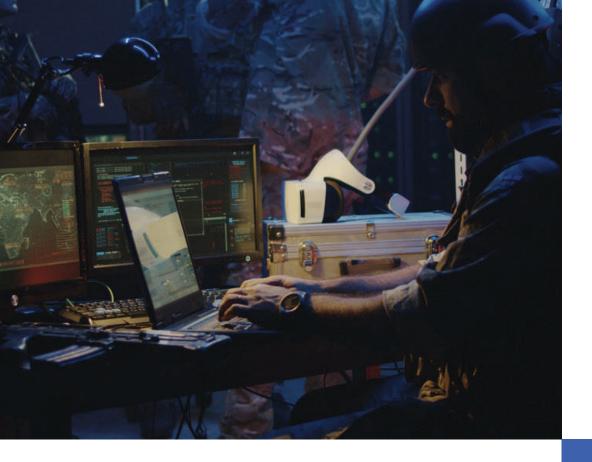
An additional time-saving feature of the SG Evo, advancing the legacy of the MVG SG series multi-probe systems, is a configurable system architecture supporting parallel receivers. Measurement time can be dramatically reduced by making simultaneous measurements using multiple receivers, an advantage for measurements at many frequencies or antenna beam states.

CUSTOMIZABLE

The modular design of the SG Evo accommodates customized builds to address a variety of requirements and test article sizes: the diameter of the probe array arch and the azimuth positioner model are selected based on the size and weight of the DUT; probes are selected based on the measurement frequencies and support 400 MHz to 30 GHz.

The capacity of the SG Evo is not limited to the measurement of phased-array antennas for satellite payloads. It is useful for other applications, such as base station antennas, and is suitable for initial prototype tests in research and development to the final validation of fully integrated antenna systems during production.

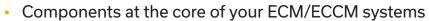
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Double-Ridge Waveguide Components

airview Microwave has added a line of double-ridge waveguide components to its extensive waveguide portfolio. Developed for radar, wireless, satellite communication, test and instrumentation, the family comprises the WRD180 (18 to 40 GHz), WRD650 (6.5 to 18 GHz) and WRD750 (7.5 to 18 GHz) sizes, with 28 models in various straight, bend and twist configurations.

The double-ridge name refers to the addition of a pair of ridges in the center of a rectangular waveguide, parallel to the short wall. Compared to a conventional rectangular waveguide, a doubleridge waveguide covers a wider frequency range, with a lower cut-off frequency.

To complement the waveguide family, double-ridge waveguide-to-coax adapters are available in the same WRD180. WRD650 and WRD750 sizes, offering SMA, type N and 2.92 mm connector options. Machined in brass with UG-style square cover flanges, the adapters are available in right-angle and end-launch configurations. Maximum VSWR is 1.5:1 for the WRD650 and WRD750 adapters and 1.65:1 for the WRD180.

Fairview Microwave's double-ridge waveguide components are in stock and available with same-day shipping to meet immediate customer needs for double-ridge waveguide transmission lines. No minimum order quantity is required.

These double-ridge waveguide and coaxial adapters join Fairview Microwave's other waveguide products and accessories, including attenuators, bandpass filters, couplers, detectors, flexible waveguide, frequency converters, horn antennas, isolators, magic tees, phase shifters, power amplifiers, switches and terminations.



Fairview Microwave Lewisville. Texas www.fairviewmicrowave.com

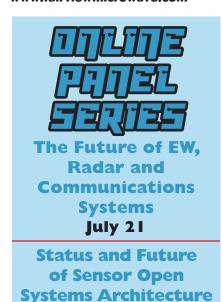


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Analog Devices

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High Performance Passive Components VENDORVIEW

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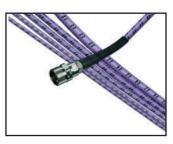
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https://literature.hubersuhner.com/Technologies/Radio-frequency/Lightningprotection/

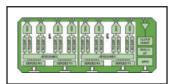


Pallet Solutions

Integra Technologies Inc., a provider of RF and microwave power semiconductor and pallet solutions for state-of-the-art radar, EW and advanced communications systems, announced a new family of S-Band pallet and transistor products based

on Integra's patented Thermally Enhanced GaN/SiC for high performance radar applications. Integra's IGN2729M400R2 pallet solution provides best-in-class gain and efficiency performance delivering 400 W. Integra offers a full selection of RF power solutions ranging from UHF through X-Band.

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90- and 180-Degree Hybrid Coupler Primer VENDORVIEW

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LadyBug Technologies

www.ladybug-tech.com/product/the-lb5940a-1-mhz-to-40-ghz-true-rms-power-sensor/



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Mini-Circuits is excited to be a part of year's IMS2021. For those who were unable to attend this year's event in person in Atlanta, June 8-9, please join us at the virtual event, June 20-25 to check out our latest technology



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Pickering Interfaces www.pickeringtest.com



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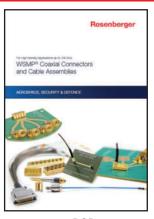
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