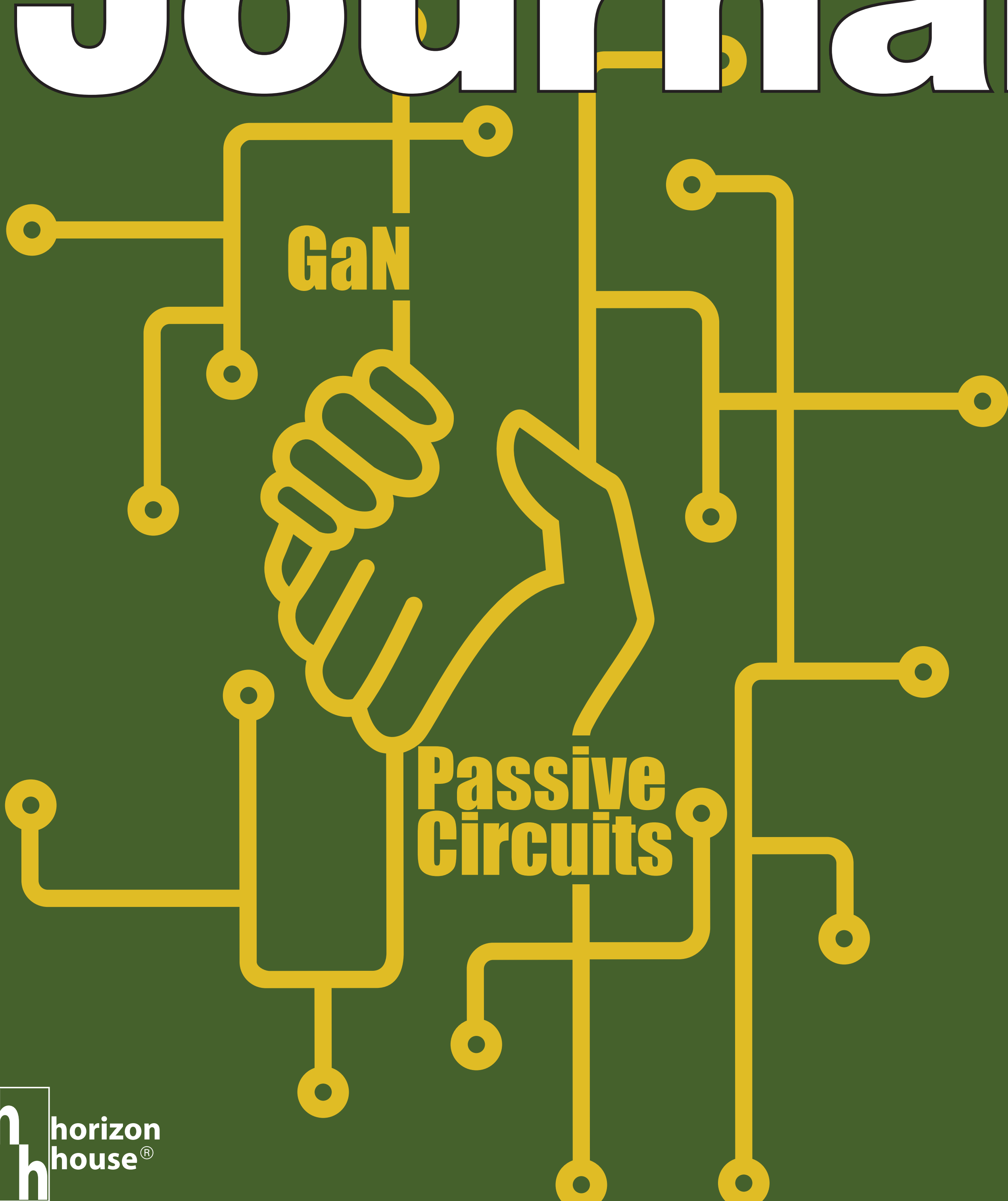
Vol. 64 • No. 10

October 2021

Microwave Journal



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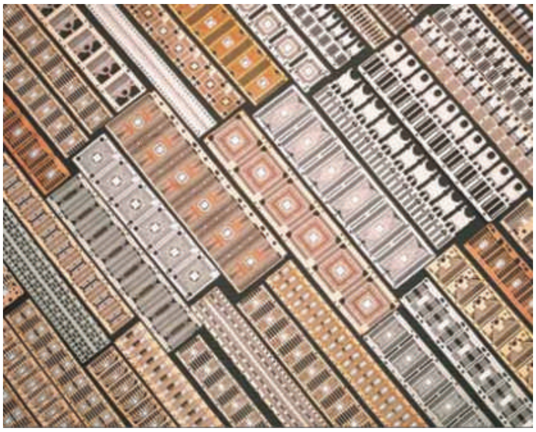

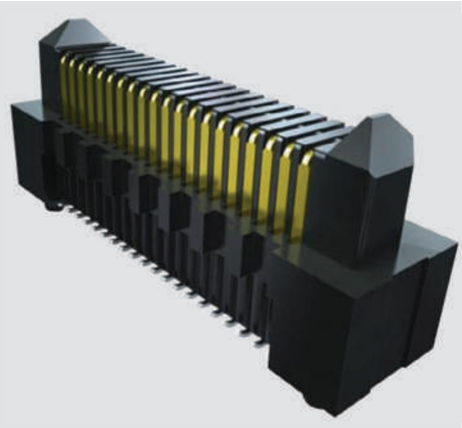

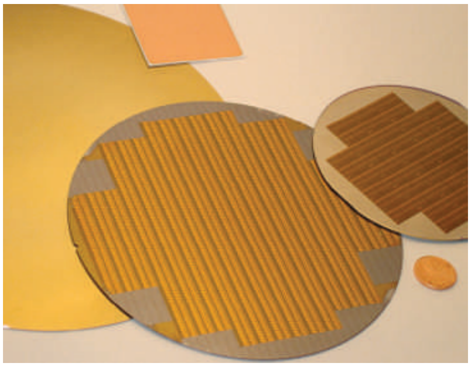

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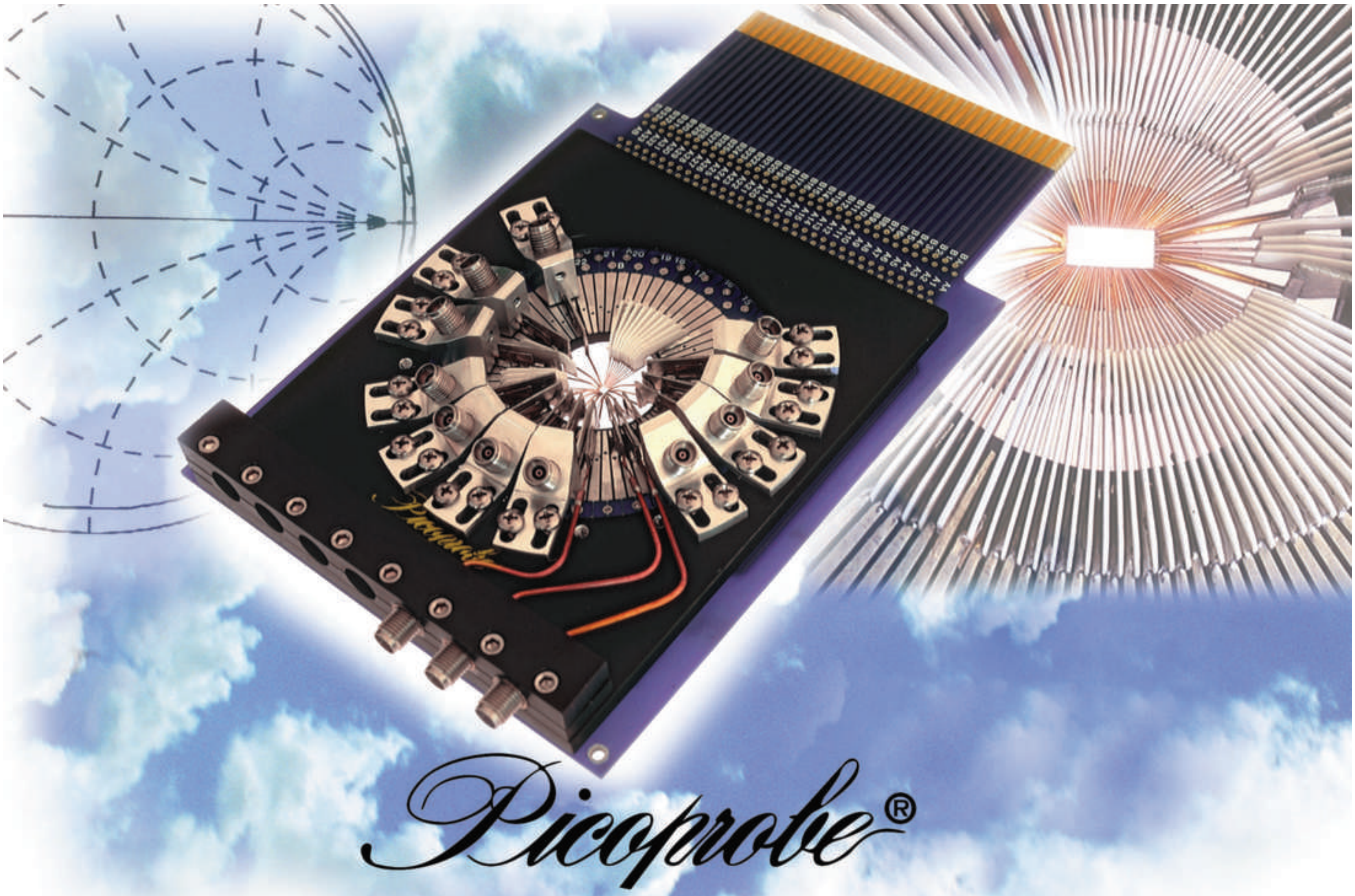

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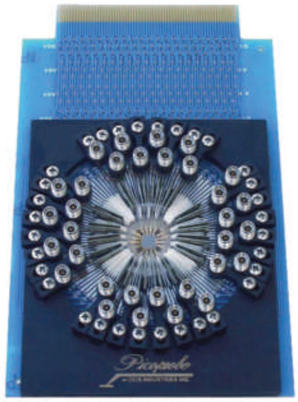

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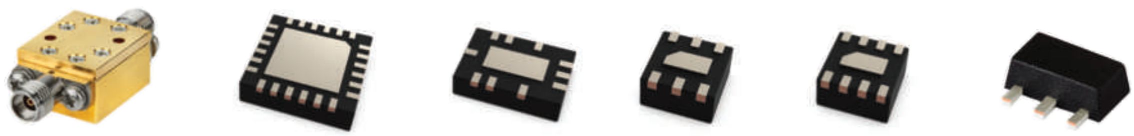

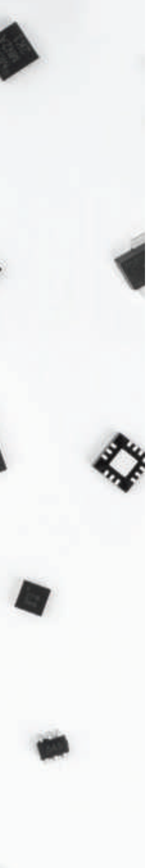

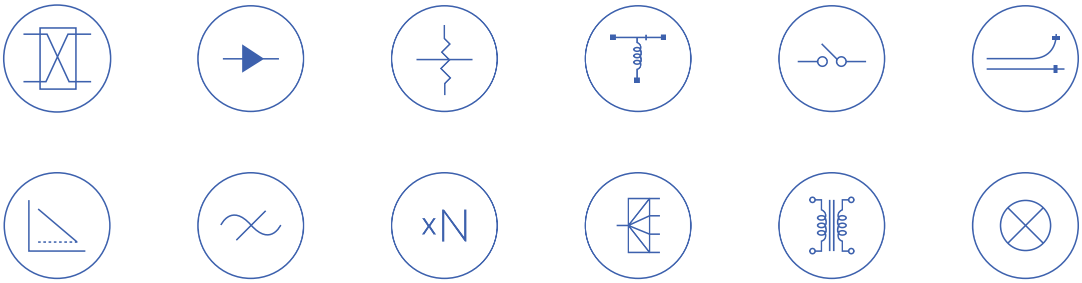

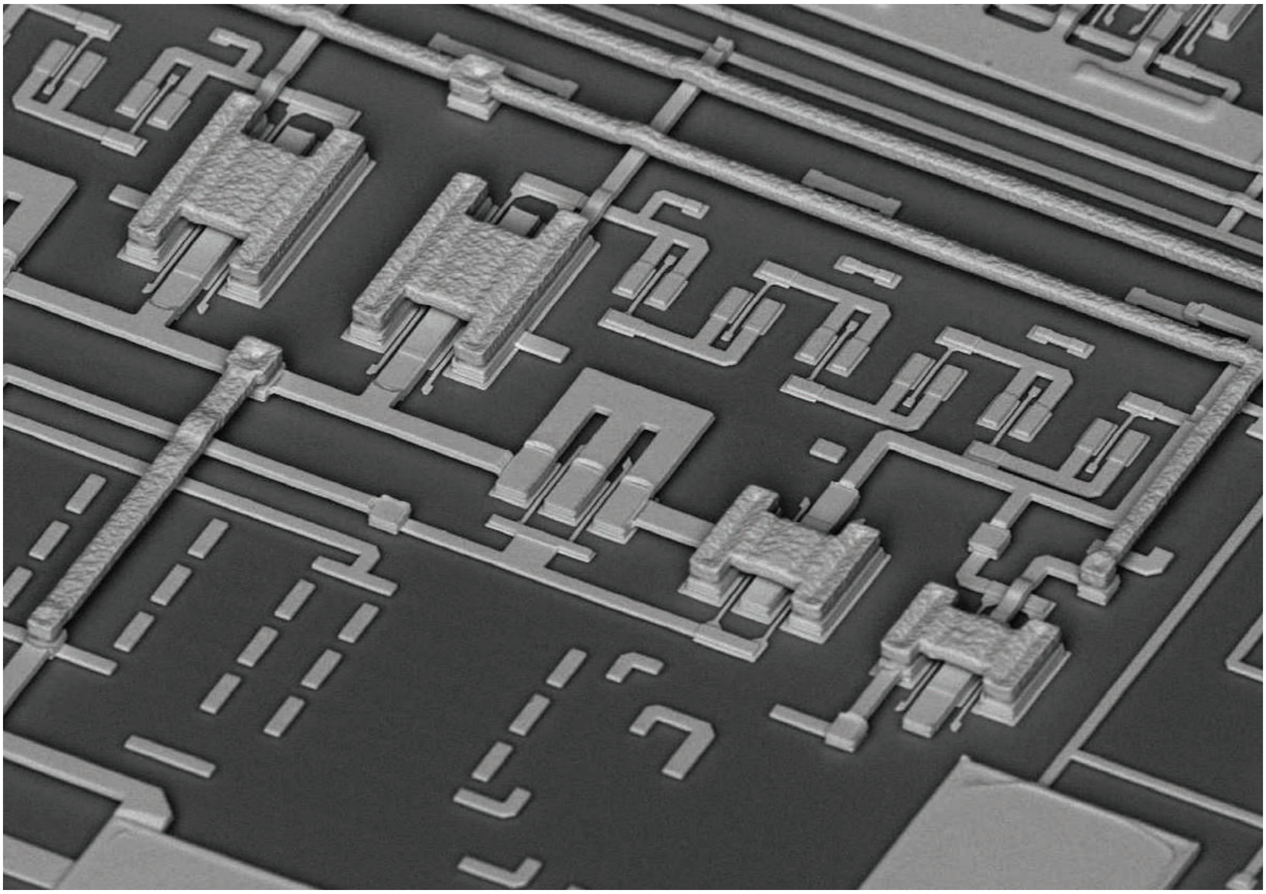

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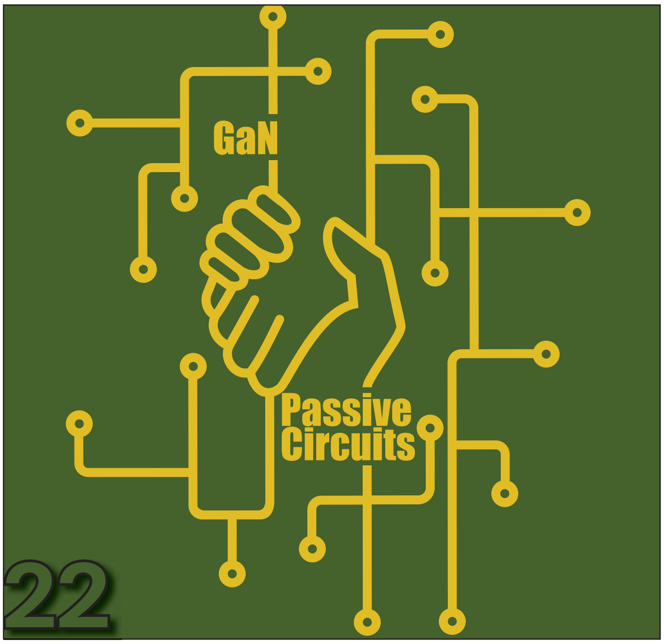

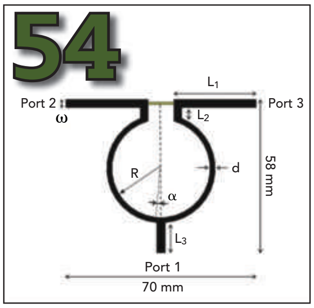

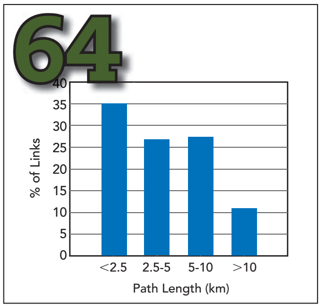

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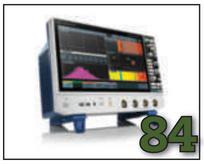

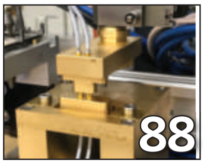

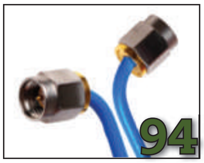

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Microwave Journal (USPS 396-250) (ISSN 0192-6225) is published monthly by Horizon House Publications Inc., 685 Canton St., Norwood, MA 02062. Periodicals postage paid at Norwood, MA 02062 and additional mailing offices.

POSTMASTER: Send address corrections to Microwave Journal, PO Box 1028, Lowell, MA 01853 or e-mail mwj@e-circ.net.com. Subscription information: (978) 671-0446. This journal is issued without charge upon written request to qualified persons working in the RF & microwave industry. Other subscriptions are: domestic, $120.00 per year, two-year subscriptions, $185.00; foreign, $200.00 per year, two-year subscriptions, $370.00; back issues (if available) and single copies, $10.00 domestic and $20.00 foreign. Claims for missing issues must be filed within 90 days of date of issue for complimentary replacement.

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Using Off-Chip Passive Components to Maximize GaN Performance & Reduce Cost

Ron Demcko and Daniel West
AVX Corporation, Greenville, S.C.

Decades of research and development dedicated to GaN RF power semiconductor technology has led to an increasing supply of affordable RF power devices with impressive performance. GaN semiconductors have reduced material capacitance and enhanced electron mobility, resulting in remarkably low conduction losses, considerably faster switching times and higher frequency-temperature and frequency-voltage characteristics than silicon technologies. Extensive lab testing conducted by numerous sources consistently demonstrates these performance advantages over competing technologies, which has hastened the deployment of GaN power devices in numerous applications. Now, design engineers worldwide are harnessing these compact, low loss and fast switching semiconductors to develop smaller, lighter and more reliable systems that extend the capabilities of solid-state RF power design.

With the many benefits of GaN come a set of challenges with new circuit designs. For example, passive components at the output of a GaN device can reduce the output power of the active component. Even if the passive components don't introduce excessive loss, they can degrade GaN's ability to operate at maximum performance. Some of these design challenges can be overcome by using high performance passive components, such as advanced capacitors and surface-mount technology (SMT) heat pipes. This symbiotic relationship between passive components and GaN RF power devices makes the capacitor selection process critical.

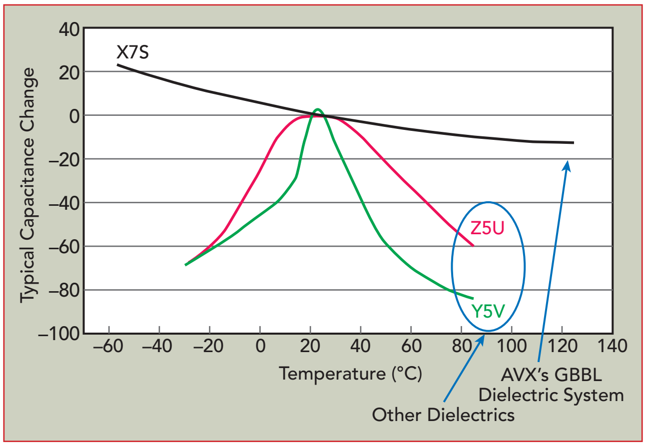

Fig. 1 **Temperature stability of Z5U, Y5V and X7S dielectrics. The GBBL material system has X7S temperature characteristics.**

This article addresses several high performance passive component technologies that pair well with GaN to provide impedance matching, bias filtering, DC blocking and thermal control, helping GaN power devices operate optimally.

SINGLE-LAYER CAPACITORS AND IMPEDANCE MATCHING

Single-layer capacitors (SLC) are comprised of a single ceramic dielectric layer with terminations for conductive epoxy attachment and wire bonding. Providing good performance through 40 GHz, they can be used in internal and external configurations—for example, playing an integral role in maximizing the power transfer of a GaN power amplifier as part of the impedance matching networks. When placed inside a device package, SLCs can be elements of a matching network between the lead frame and gate of the transistor, helping provide a broadband impedance match at the input of the device. Used outside the package, SLCs can be used for impedance matching, DC blocking and broadband bypassing. SLCs can be configured as single, dual or multiple SLC arrays to minimize component count.

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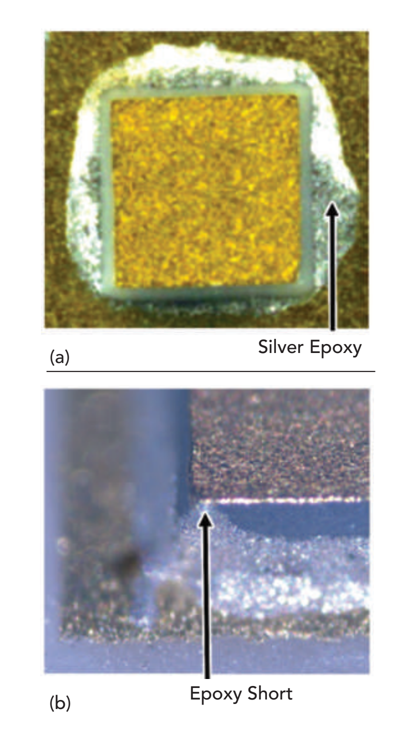

Fig. 2 Bordered (a) and non-bordered (b) SLCs. Excess conductive epoxy can climb up the sidewall of a non-bordered SLC and cause a short. *Source:* TJ Green Associates, LLC.[1]

their construction. The two most common dielectrics are SiO_2 and C0G (NP0) EIA Class I temperature-compensating ceramic. Both have high temperature stability (0 ±30 ppm/°C), ideal for impedance matching where temperatures are high and thermal stability is critical. A new type of dielectric, the grain boundary barrier layer (GBBL) material system, has demonstrated noteworthy performance as a replace-

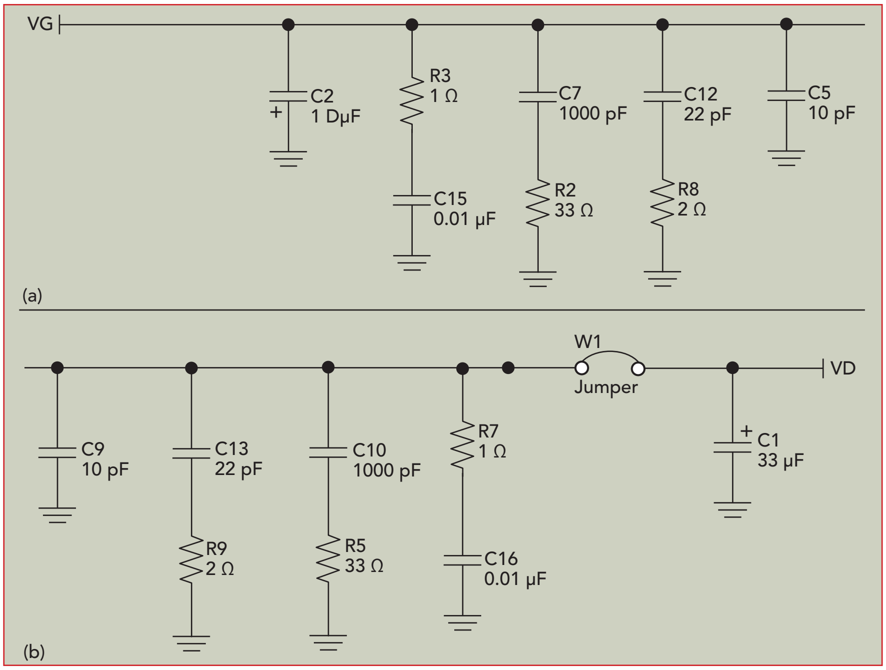

Fig. 3 Gate (a) and drain (b) bias filter banks. *Source:* Qorvo.[2]

ment for the general-purpose Z5U and Y5V ceramic dielectrics where bulk capacitance is a concern. A typical GBBL dielectric exhibits X7S temperature characteristics with better temperature stability compared to the Z5U and Y5V dielectrics (see ***Figure 1***).

SLC terminations are typically comprised of sputtered TiW/Au or TiW/Ni/Au. This combination of sputtered materials yields thin, high-quality termination surfaces with excellent adhesion, essential for conductive epoxy attachment and wire bonding, particularly with high-power RF devices subject to severe temperature cycling. The terminations can be bordered, which means the metallization does not extend to the capacitor edges, or non-bordered, which means it does (see ***Figure 2***). Bordered SLCs minimize the chance of conductive epoxy climbing the sidewalls to touch the top plate and short the capacitor. Ideally, epoxy fillets should flow about halfway up the side of an SLC, but since MIL-SPEC requirements don't specifically specify conductive epoxy fillet height on die edges, using bordered SLCs can avoid the possible negative outcome from overflow.[1] Non-bordered SLCs are typically used in source bypass configurations because they reduce the bond length between the top termination and the active device.

BULK CAPACITORS FOR BIAS FILTERING

GaN power devices require a stable bias voltage for optimum operation. Since bulk capacitor banks are stable with voltage and temperature and have good aging characteristics, they are often used to filter bias line noise and provide a fast source of charge to supply the high current changes ($\Delta i/\Delta t$) in a power amplifier (see ***Figure 3***). The transient response of these filter capacitor banks is determined by the combination of high capacitance and high frequency response. Bulk capacitors suitable for voltage bias banks include high-CV multilayered ceramic capacitors (MLCC) and tantalum, tantalum-polymer, aluminum and aluminum-polymer electrolytic capacitors (see ***Figure 4***).

While high-CV MLCCs can achieve the capacitance ranges required for many bias networks, they don't provide stable capacitance values across operating conditions such as temperature, time and DC bias.[3] For example, the capacitance stability of a 100 μF X5R MLCC can vary from 100 μF at 25°C to approximately 85 μF at -55°C and 80 μF at 125°C. High-CV MLCCs also suffer from DC bias voltage effects that can significantly reduce the capacitance value present in the circuit. For example, the capacitance value of a Class II MLCC can decrease by 35 to 65 percent at the fully rated DC current. Additionally, low voltage AC ripple current can further reduce the capacitance of high-CV MLCCs by another 5 percent, and aging can reduce the capacitance by another 2 to 5 percent per decade. Depending on the operating conditions and the MLCC chosen, all these losses combined with the temperature coefficient can reduce the total expected


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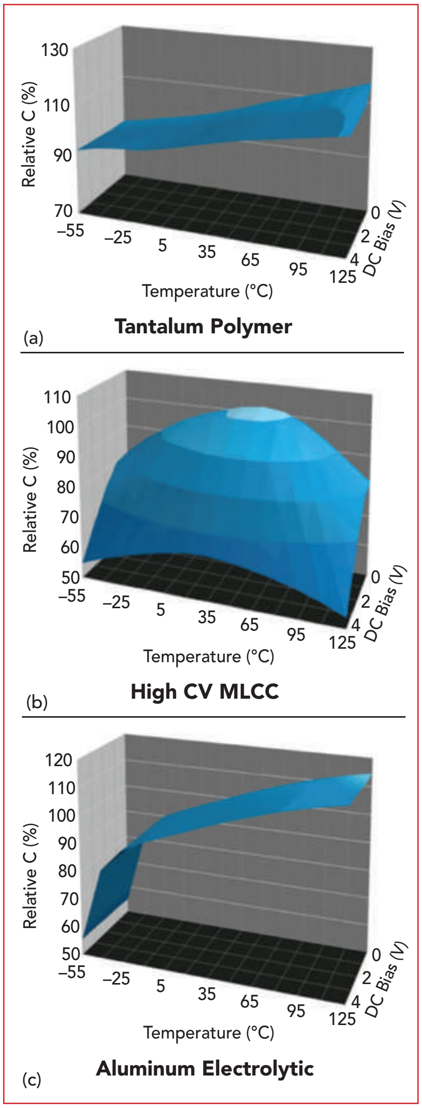
capacitance of high-CV MLCCs by approximately 80 percent.

The remaining bulk capacitor options suitable for bias filtering include traditional and polymer versions of tantalum and aluminum electrolytic capacitors. Although this article focuses on tantalum bulk capacitors for bias filtering, aluminum capacitor technology and performance are also improving. Tantalum capacitors have size, weight and stability advantages over traditional aluminum electrolytic capacitors. For example, tantalum capacitors have an average capacitance of 0.6 μF/mm^3 compared to miniature aluminum electrolytic capacitors, which have an average capacitance of 0.1 μF/mm^3. Tantalum-polymer capacitors exhibit approximately one-eighth the equivalent series resistance of traditional tantalum capacitors, meaning a current capacity approximately 8× of traditional tantalum capacitors. Advances in tantalum-polymer capacitor technologies have also extended the voltage rating of miniature SMT capacitors to 125 V. While traditional tantalum capacitors require 50 percent derating, tantalum-polymer capacitors rated up to 16 V only require 10 percent derating for polymer substrate devices and 20 percent derating for those rated for greater than 16 V operation.

Tantalum and tantalum-polymer capacitors are available in multiple case sizes with reduced height profiles relative to aluminum electrolytic capacitors and with novel lead frame packages that have dramatically lower inductances than aluminum electrolytic capacitors (see ***Table 1*** and ***Figure 5***). This enables bulk capacitor designs with better fit. As such, both tantalum and tantalum-polymer



▲ Fig. 4 Capacitance stability, DC bias and temperature performance for tantalum polymer (a), high-CV MLCC (b) and aluminum electrolytic (c) capacitors.

capacitors are highly competitive with aluminum electrolytics and well suited for use in GaN power amplifier designs, despite their derating.

UNIQUE CAPACITORS AND DC BLOCKING

Another passive component requirement for GaN power amplifiers is DC blocking. DC blocking in circuits operating at higher frequencies and wide bandwidths requires stable, low loss capacitors that can be easily configured to the circuit. Three unique capacitor technologies are worth considering: ultra-broadband capacitors (UBC), metal-insulator-metal (MIM) capacitors and metal oxide semiconductor (MOS) capacitors (see ***Figure 6***). While there are additional options, these three types have proven to be practical for DC blocking.

UBCs — UBCs have a multilayered ceramic dielectric form factor that is compatible with standard printed circuit board manufacturing, including fully automated, high speed pick-and-place processing. They are available in 0201 and 0402 package sizes to match transmission lines, respectively, rated for 10 and 100 nF and they have ultra-low insertion loss, flat frequency response and excellent return loss from 16 kHz to approximately 70 GHz (see

TABLE 1
TANTALUM CAPACITOR CASE SIZES AND INDUCTANCE

Case Size	Inductance (nH)
Standard Devices	
A	1.8
B	1.8
C	2.2
D	2.4
E	2.5
F	2.2
G	1.8
H	1.8
K	1.8
N	1.4
P	1.4
R	1.4
S	1.8
T	1.8
U	2.4
V	2.4
W	2.2
X	2.4
Y	2.4
5	2.4
Low-Profile Devices	
K	1
L	1
M	1.3
N	1.3
O	1
S	1
T	1
Multianode Devices	
D	1
E	2.5
U	2.4
V	2.4
Y	1
D	1

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- Pulse Modulators (SPST)
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- Receiver Front Ends & Transceivers
- SDLVAs, ERDLVAs & DLVAs
- Single Side Band Modulators
- SMT & QFN Products
- Switch Matrices
- Switched Filter Banks
- Switches – Solid State
- Systems - Radar Sense & Avoid
- Systems – Fly Eye Radars
- Threshold Detectors
- USB Products

PLNA-30-10M6G-P1dB22-120VAC

PLNA-35-100M18G-P1dB24-120VAC

PEC-50-0R118-6R5-18-120VAC-1U-SFF
PTB-40-0R118-6R5-21-120VAC-1U-SFF-OPT10M6G

PTB-35-120-5R0-10-115VAC-SFF-2U
PTB-60-120-5R0-10-115VAC-SFF-2U

PTB-35-120-5R0-10-115-VAC-SFF
PTB-60-120-5R0-10-100VAC-SFF

PMI Model No.	Frequency Range (GHz)	Gain (dB Typ)	Noise Figure (dB Typ)	OP1dB (dBm Typ)	Size (Inches) Connectors
PLNA-30-10M6G-P1dB22-120VAC	0.01 - 6	30	4.5	+22	3.0" x 3.0" x 1.75" Type N (F)
PTB-40-0R118-6R5-21-120VAC-1U-SFF-OPT10M6G	0.01 - 6	40	4.5	+22	19" Rack Mount 1U Height, 10" Depth SMA (F)
PLNA-35-100M18G-P1dB24-120VAC	0.1 - 18	40	3.5	+25	3.5" x 3.5" x 1.75" Type N (F)
PEC-50-0R118-6R5-18-120VAC-1U-SFF	0.1 - 18	50	4.0	+14	19" Rack Mount 1U Height, 10" Depth SMA (F)
PTB-35-120-5R0-10-115VAC-SFF-2U	1 - 20	35	5.5	+10	19" Rack Mount 2U Height, 10" Depth SMA (F)
PTB-60-120-5R0-10-115VAC-SFF-2U	1 - 20	60	5.5	+10	19" Rack Mount 2U Height, 10" Depth SMA (F)
PTB-35-120-5R0-10-115-VAC-SFF	1 - 20	35	5.0	+10	4.92" x 4.92" x 2.26" SMA (F)
PTB-60-120-5R0-10-100VAC-SFF	1 - 20	60	5.0	+10	4.92" x 4.92" x 2.26" SMA (F)
PTB-42-1G40G-12-292FF-DC12-100VAC	1 - 40	40	5.0	+22 (1-18) +18 (18-40)	4.92" x4.92" x 2.26" 2.92mm (F)
PTB-42-1G40G-12-292FF-DC12-220VAC	1 - 40	40	5.0	+22 (1-18) +18 (18-40)	4.92" x 4.92" x 2.26" 2.92mm (F)
PTB-50-1G40G-12-292FF-DC12-220VAC	1 - 40	50	4.0	+22 (1-18) +18 (18-40)	4.92" x 4.92" x 2.10" 2.92mm (F)
PTB-30-2040-5R0-10-220VAC-292FF	20 - 40	30	5.0	+10	4.92" x 4.92" x 2.26" 2.92mm (F)
PTB-60-2040-5R0-10-100VAC-292FF	20 - 40	60	5.0	+10	4.92" x 4.92" x 2.26" 2.92mm (F)
PTB-60-2040-5R0-10-220VAC-292FF	20 - 40	60	5.0	+10	4.92" x 4.92" x 2.26" 2.92mm (F)

PTB-42-1G40G-12-292FF-DC12-100VAC
PTB-42-1G40G-12-292FF-DC12-220VAC

PTB-50-1G40G-12-292FF-DC12-220VAC

PTB-30-2040-5R0-10-220VAC-292FF
PTB-60-2040-5R0-10-100VAC-292FF
PTB-60-2040-5R0-10-220VAC-292FF

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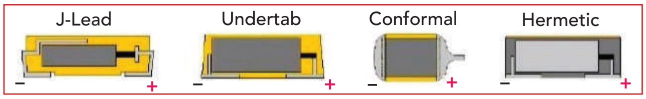

Fig. 5 Tantalum capacitor packaging options.

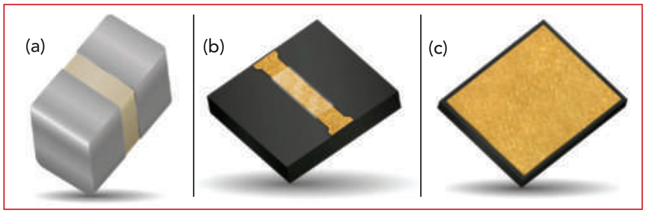

Fig. 6 UBC (a), MIM (b) and MOS (c) capacitors.

Figure 7). UBCs are an optimal passive component for DC blocking, DC coupling, bypass and feedback circuits in GaN power amplifiers.

MIM Capacitors — MIM capacitors are small, have low loss and can be used to compensate for the inductance effects of wire bond attachments, making them useful for DC blocking in high frequency transmit and receive stages. MIM capacitors use quartz, alumina or glass substrates to minimize loss and have a transmission line wire bond pad with backside ground to extend the frequency performance and reduce loss. Copper traces maximize conductivity, and front and backside gold metallization are compatible with high integrity epoxy, gold wire or ribbon attachment. They have 60 ppm/°C temperature stability with capacitance values from 0.3 to 15 pF and up to 100 V operating voltage. Custom capacitors can be designed, using a 50 to 100 pF/mm^2 capacitance to area ratio.

MOS Capacitors — MOS capacitors are SLCs with SiO_2 dielectrics and are small, temperature-stable capacitors with high Q, high breakdown voltage and low leakage. Manufactured with copper terminations in standard or custom patterns, MOS capacitors can be as thin as 127 µm for integration in 2.5D and 3D multi-chip modules, enabling higher frequency and lower power designs—potentially eliminating the wire bonds to the capacitor to reduce series inductance and extend the frequency response. Other termination options are gold or aluminum metallization on the top side and no metallization silicon, gold on bare silicon or chrome-gold on

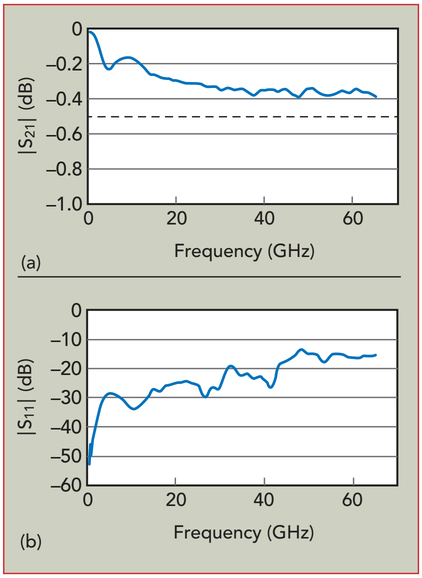

Fig. 7 Typical $|S_{21}|$ (a) and $|S_{11}|$ (b) of the 550L series UBCs.


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the bottom. Standard MOS capacitors are compatible with epoxy and solder die attachment and gold or aluminum wire bonding. Standard sizes and capacitance values range from 0.010 to 0.070 in.^{2} and 1.0 to 1,000 pF, respectively.

SMT HEAT PIPES

A signature benefit of GaN power devices is their ability to deliver high power in a small package. This can generate a massive amount of heat in a small area, requiring thermal control methods to remove, spread and couple the heat from the active device to get maximum performance and ensure reliability.

The thermal challenges of GaN can benefit from novel solutions like miniature SMT heat pipes.[4] Miniature SMT heat pipes are a cost-effective solution for providing additional heat flow from the pins of an active device. Unlike traditional heat pipes, SMT heat pipes deliver high thermal conductivity with reduced parasitic capacitance, higher insulation resistance and high breakdown voltage. The small size of the SMT heat pipe supports the requirements for small size, weight and power (SWaP) designs. Although performance depends on the case size, the typical parasitic capacitance for the standard 0402, 0603 and 0805 EIA sizes is just 0.04 to 0.13 pF and the typical thermal conductivity is from 40 to greater than 500 mW/°C.

Miniature SMT heat pipes are available with several terminations: Sn/Ni/Pt, Ag/Pt and non-magnetic Ag. Custom SMT heat pipes have been designed to optimize the heat flow around MMICs, other high-power devices have been developed in case sizes spanning 0302 to 3737.

To illustrate the effectiveness of the SMT heat pipe, AVX engineers performed infrared (IR) measure-

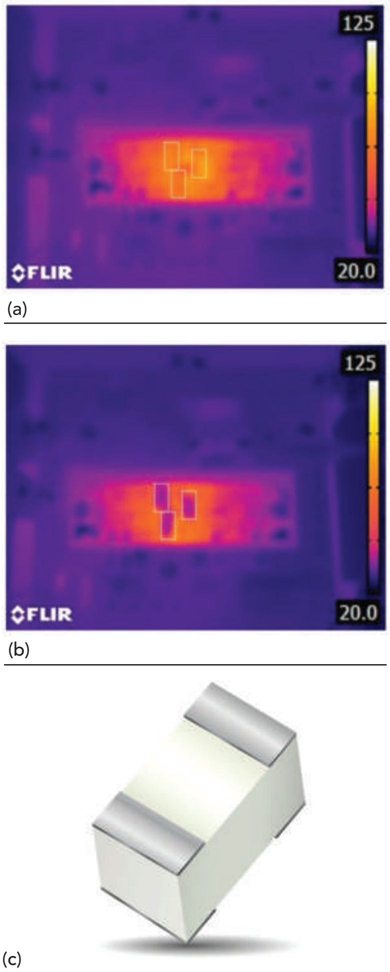

Fig. 8 IR thermal scan of a 100-W GaN PA MMIC without heat pipes (a) compared to the PA using three heat pipes (b). Q-Bridge SMT heat pipe (c).

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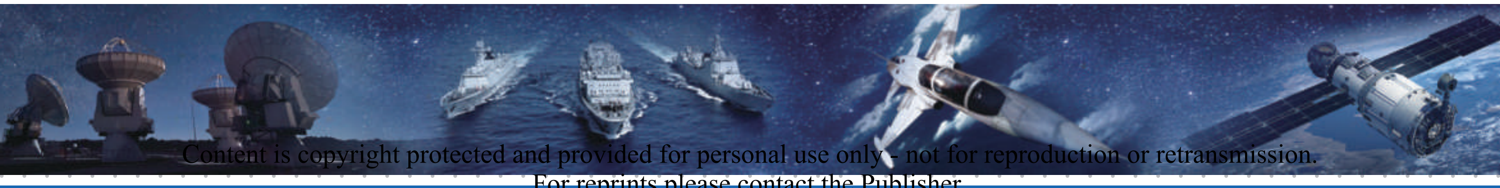

ments on an ultraminiature, high performance GaN power amplifier MMIC rated for 100 W output power. The MMIC was operated with a CW signal for 20 seconds at the amplifier's center frequency, measuring the thermal rise with no heat pipes and using three Q-Bridge SMT heat pipes. Using the heat pipes, the IR measurement showed a 38°C decrease in MMIC temperature without any design modifications (see ***Figure 8***), from approximately 80°C with no heat pipes to 42°C using the heat pipes. Neither the MMIC nor the larger power amplifier assembly were designed to include the Q-Bridge SMT heat pipes, i.e., the test was run with an existing design. Arguably, greater heat reduction could have been demonstrated if the power amplifier had been designed to include these SMT heat pipes.

SUMMARY

GaN RF power devices have been proven through extensive lab tests and products, hastening their deployment for defense and commercial applications, in turn driving prices down and increasing accessibility. To fully realize GaN's impressive performance—reduced capacitance, higher electron mobility, low conduction losses, faster switching and higher frequency-temperature and frequency-voltage characteristics than silicon—engineers must pair GaN devices with high performance passive components. Passive components are important circuit elements for impedance matching, bias filtering, DC blocking and thermal management. Without paying attention to the effects of these passive components, designers risk limiting the technology from reaching the full capabilities of its performance.

The development of new material systems, such as the GBBL ceramic dielectrics for SLCs and conductive polymers for tantalum bulk capacitors, are enabling designers to mitigate these potential performance limitations. New capacitor sizes and package styles are enabling smaller layouts to support SWaP requirements and improve electrical performance. New devices like SMT heat pipes are expanding the solutions available for removing, spreading and coupling the heat from the higher power density of GaN—improving both performance and reliability.

As GaN device technology continues to evolve and deliver improved performance, new and improved passive component technologies will be engineered to support these impressively compact, low loss and fast switching semiconductors, leading to the next generation of smaller, lighter and more reliable RF power amplifiers. ■

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DREAM ON

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

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

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

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

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

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

JTK: When did you join the company?

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

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

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

JTK: What markets are your products designed for?

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

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

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

JTK: How would you describe the Marki Microwave culture?

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

JTK: Are you hiring?

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

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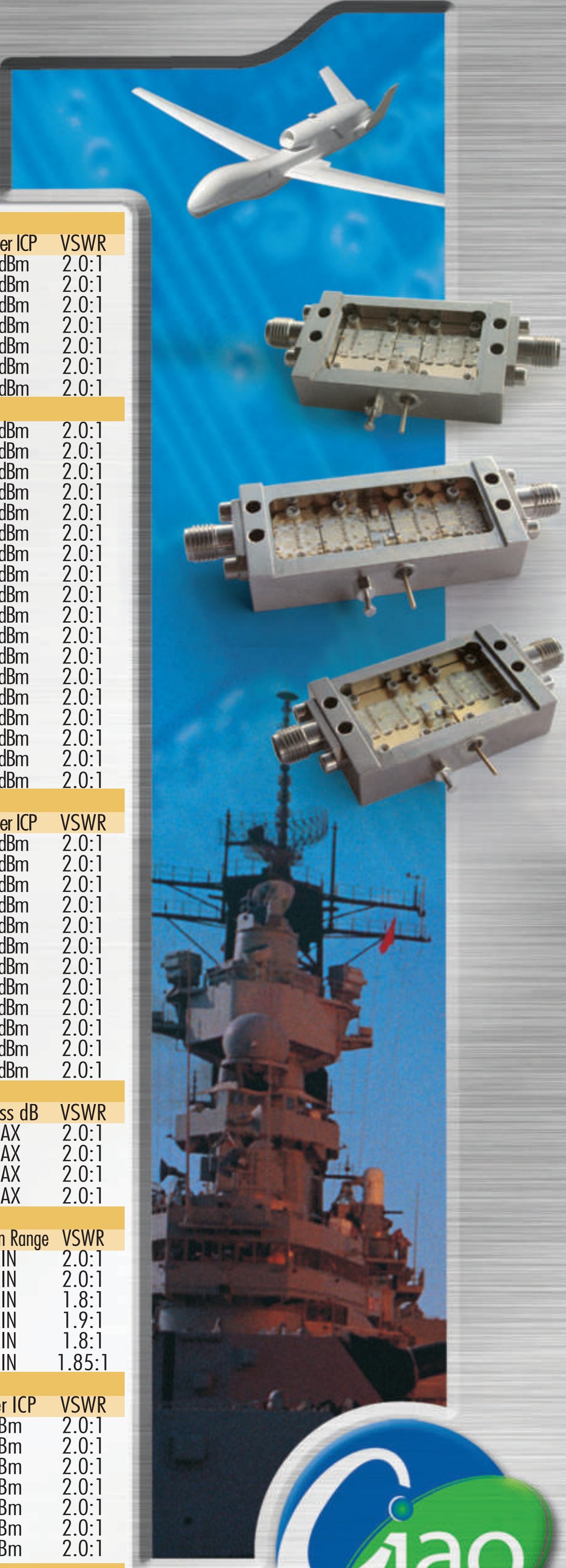

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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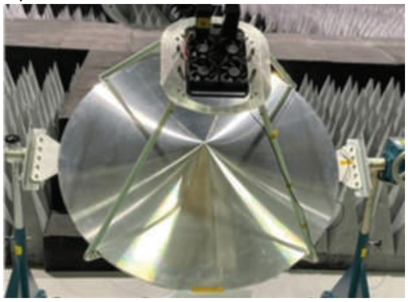
High Performance, Low-Cost Hybrid Antenna for 5G, Radar and Remote Sensing

Lockheed Martin has invented a new type of satellite dish technology with a wide range of uses on satellites and ground terminals, including space-based 5G. The Wide-Angle ESA Fed Reflector (WAEFR) antenna is a hybrid of a phased array electronically steerable antenna (ESA) and a parabolic dish, increasing coverage area by 190 percent compared to traditional phased array antennas at a much lower cost.

This antenna is part of a larger research and development investment in 5G.MIL™ technologies that will optimize and securely connect warfighting platforms to enable joint all-domain command and control (JADC2). Lockheed Martin is uniquely positioned, leveraging commercial best practices, strong partnerships, a broad supply chain and leadership expertise, to bring 5G connectivity and capabilities to the defense community rapidly and affordably.



Hybrid Antenna (Source: Lockheed Martin)

"We adopted a commercial mindset to quickly mature this technology and discovered there were multiple use cases and applications that could benefit from this new hybrid antenna," said Chris Herring, vice president of advanced program development at Lockheed Martin Space. "5G.MIL technologies like this will bring greater connectivity, faster and more reliable networks and new data capabilities to support our customers as they navigate the complexity of 21st century battlefields."

The team rapidly prototyped, tested and validated this system in a matter of months compared to what previously took years. WAEFR also features:

- High performance gain of a dish with the beam agility of an ESA
- Low size, weight and power common product solution to accommodate any orbital altitude or ground terminal application
- Advances in 3D printing technology and accelerated parts production.

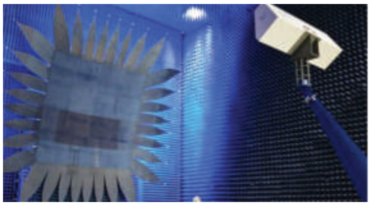
This type of antenna will also benefit the broader communications and ISR communities by providing a more reliable scanning solution compared to gimbaled designs.

DARPA Transitions Next-Generation Phased Array System to Support Future Defense R&D

DARPA recently announced that a first-of-its-kind sensor system developed under the Arrays at Commercial Timescales–Integration and Validation (ACT-IV) program has transitioned to the Air Force Research Laboratory (AFRL) for continued advancement and experimentation. Northrop Grumman, the primary research team on the ACT-IV program, facilitated the transition of the advanced digital active electronically scanned array (AESA) to the Wright-Patterson Air Force Base in Dayton, Ohio.

ACT-IV is a novel multifunction AESA system that is capable of simultaneously performing different operations, such as radar, electronic warfare (EW) and communications functions, at different modes. At the system's core is an advanced semiconductor device—or common module—fabricated in commercial silicon that was originally developed by DARPA's Arrays at Commercial Timescales (ACT) program. Now concluded, the ACT program sought to shorten phased array design cycles and simplify the process of upgrading fielded capabilities. The ACT common module—a digitally-interconnected building block from which large systems can be formed—was developed as a more efficient alternative to substantial undertakings with traditional monolithic array systems. In addition to the ACT module, the ACT-IV system employs a computational model capable of efficiently receiving and computing on the significant amounts of input data generated by each module.

"With the ACT-IV program, we were able to realize the vision of ACT by developing an advanced sensor system with ACT common modules," said Tom Rondeau, the program manager leading ACT-IV. "The resulting system went through extensive testing and demonstrations to validate its capabilities, proving out a sixth-generation array with a scalable, customizable core that could work across varied application spaces. Transitioning the ACT-IV system to AFRL will enable continued exploration of digital, multifunctional RF technologies for defense needs."



ACT-IV (Source: DARPA)

Another critical aspect of the ACT-IV program was the creation of a third-party developer community to enable continued use and advancement of the technologies. Teams from government research labs and university-affiliated research centers developed a curriculum and training program that provides developers and researchers with the necessary knowledge and know-how to continue building on the work of the ACT-IV program. The growing community has already generated a number of

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tools and applications, including a more agile software development model for RF phased arrays.

At the Wright-Patterson Air Force Base, the ACT-IV system will become a Department of Defense (DoD)-wide asset for testing and experimentation with new modes of radar, communications, sensing and EW. The software, algorithms and capabilities developed on the program will also transition to next-generation multifunction RF systems to support advanced defense development programs and a future open-architecture environment.

Enhanced Perception and Sensing Capabilities for Autonomous Platforms

Sarcos Defense and BAE Systems plc are partnering to develop advanced perception and sensing capabilities for autonomous platforms for AFRL to benefit DoD operations. Sarcos and BAE Systems FAST Labs™ were awarded a $1.699M contract by AFRL (Rome, N.Y.) to work on a collaborative sensing platform (BAA FA8750-20-S-7014). The work is expected to continue through 2023, culminating with the demonstration of the new solution.

This platform aims to address the complex issues that involve the coordination of both individual and multiple cooperating heterogeneous autonomous platforms, including unmanned aircraft systems and unmanned ground vehicles equipped with standard multi-modal sensors, such as cameras, radar and LiDAR. The expected result will coalesce multiple environmental inputs and combine with AI and machine learning technologies to enable unmanned systems to work together in greater harmony, both alone and coordinating with each other in "swarm" scenarios. The platform will enable better situational awareness and safety, including accurate detection, tracking and classification of time-critical objects, particularly in unstructured environments.

Sarcos expects to apply this research in its commercial robotics products, particularly in its forthcoming Cybernetic Training for Autonomous Robots (CYTAR™) AI platform, which Sarcos is also working with AFRL to develop. Learnings will be leveraged to further improve situational awareness and safety for Sarcos' robotic technologies, including its Guardian® XT™ highly dexterous teleoperated robot and Guardian® XO® full-body, battery-powered industrial exoskeleton.

"We look forward to seeing the results of this research project and the potential impact it may have on our U.S. defense operations," said Dr. Peter Zulch, AFRL. Better perception and improving sensing lags are critical challenges, particularly as autonomous systems become more widely used."

Over 139,000 Highly Automated Commercial Vehicles Expected to Ship Globally in 2026

As factory production begins for leading OEMs within the next three years, SAE Level 4 anatonomy will move from modified heavy-duty trucks and pilots to a reality across multiple regions. According to ABI Research, these vehicle shipments will rise worldwide by 186 percent from 2024 to 2026."GaN has the promise of increased market share in 2013 and is forecast to be a significant force by 2021," noted Lance Wilson, research director, Mobile Networks. "It bridges the gap between two older technologies, exhibiting the high frequency performance of GaAs combined with the power-handling capabilities of silicon LDMOS. It is now a mainstream technology that has achieved measurable market share and in the future will capture a significant part of the market."

> Production-grade autonomous transport begins to scale.

"TuSimple with Navistar plans to launch in 2024, with their Autonomous Freight Network underway with partners like Penske Truck Leasing. Others gaining momentum include Plus, planned for 2024 and IPO candidate Aurora, anticipating integration with PACCAR and Volvo in 2023," stated Susan Beardslee, principal analyst, Supply Chain Management and Logistics at ABI Research. OEMs, along with start-ups and established partners like Intel's Mobileye and HERE Technologies, are moving rapidly toward commercialization across North America, Europe and Asia.

Driver shortages, rising insurance rates, "nuclear" verdicts and growing fuel costs all contribute to a desire for greater autonomy. Fleets must concurrently address the pressing needs to support massive e-commerce demand, profitability and regulations on hours of service. Furthermore, additive regulations at the country-level need to address capabilities and restrictions, across modalities for SAE Level 4 operations.

"The next five years will demonstrate viability, safety and revenue paths for real-world highly automated driving, with a focus on heavy-duty vehicles on highways and delivery vehicles on city roads," Beardslee concluded.

Global Private 5G Network Market Size, Share & Trends

According to ResearchAndMarkets.com's recent market report, "Private 5G Network Market Size, Share & Trends Analysis Report by Frequency, by Spectrum, by Component, by Vertical, and Segment Forecasts, 2021-2028," the global private 5G network market size is estimated to reach USD 14.28 billion by 2028, registering a CAGR of 39.7 percent from 2021 to 2028.

Significantly growing demand for ultra-reliable low latency connectivity with an extremely secure network across several mission-critical applications, such as public safety, is expected to boost the deployment of private 5G networks during the forecast period. Moreover, a wide range of industries, including manufacturing, oil and gas, mining and energy and utility, are investing a massive amount in deploying private 5G telecom services to enhance their overall productivity and operational efficiency. As a result, it is expected to foster market growth from 2021 to 2028.

The private 5G network is expected to completely transform the transportation and logistics industry by providing seamless vehicle-to-vehicle and vehicle-to-infrastructure connectivity. As such, the need to ensure a secure, seamless and uninterrupted connectivity with ports, vessels and ships is estimated to drive the market. At the same time, the continued deployment of private 5G infrastructure is estimated to improve the operational efficiencies in several Industrial IoT (IIoT) use cases. The IIoT use cases include automated guided vehicles, wireless UHD cameras, machine control systems, collaborative/cloud robots and remote asset monitoring. Thus, the rising need for higher and secure bandwidth to ensure reliable and unified communication between IIoT devices is expected to propel the market growth over the forecast period.

Key market players are strategically building partnerships with industry giants to set up a private 5G due to the ongoing COVID-19 pandemic, several key countries, such as the U.S., France, the U.K. and Australia, have temporarily postponed the 5G spectrum auctions. The pandemic has also hampered the production and supply of major telecom equipment needed to deploy the network infrastructure. As a result, it is anticipated to slow market growth over the forecast period.

5G FWA, the Fastest Growing Residential Broadband Service

The worldwide residential broadband market reached a subscriber's base of over 1.1 billion in 2020, a 4 percent increase from the previous year. Not surprisingly, the COVID-19 pandemic accelerated demand for broadband connectivity. The need for high capacity residential broadband will remain strong, even after the pandemic recovery. According to ABI Research, 5G Fixed Wireless Access (FWA) will be the fastest growing residential broadband segment to increase at a CAGR of 71 percent, exceed-

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ing 58 million subscribers in 2026.

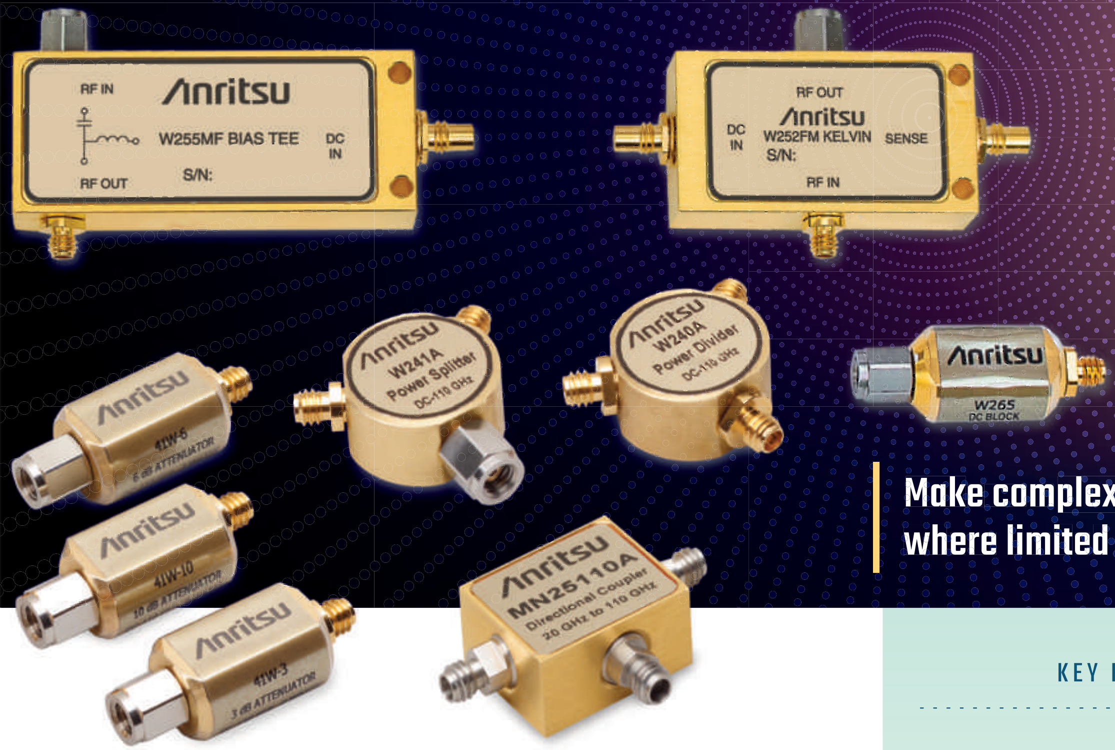
Remote working, online learning, e-commerce and virtual healthcare drove high speed broadband demand throughout 2020. The significant increase in the use of internet-based home entertainment, such as video streaming and online gaming, also pushed existing broadband users to upgrade their broadband service to a higher-tier package, while households without broadband access signed up for new subscriptions. "Increasing adoption of internet-connected devices, smart TVs and smart home devices, as well as consumers' media consumption through internet applications, will continue to drive high speed broadband adoption in the years to come. In addition, many businesses are allowing remote working for some of their employees after the pandemic, which will boost the need for home broadband services even further," explained Khin Sandi Lynn, industry analyst at ABI Research.

To fulfill demand, broadband operators are investing heavily in expanding higher capacity broadband networks. While some cable operators continue to invest in and upgrade to the DOCSIS 3.1 specification, the cable standardization body, CableLabs and other industry players are already working toward DOCSIS 4.0 technology. "Although cable companies don't anticipate the need to deploy the new cable standard any time soon, Comcast completed a lab test of DOCSIS 4.0 full-duplex system-on-chip from Broadband in April 2021. Cable companies are likely to stretch the life of the existing DOCSIS 3.1 standard for a few more years. However, DOCSIS 4.0 can support speeds of up to 10 Gbps downstream and 6 Gbps upstream, enabling improved customer experiences as well as the use of AR/VR or bandwidth-demanding services, which will certainly emerge in the future," said Lynn.

Similarly, telcos continue to upgrade their xDSL to fiber-to-the-home networks. In addition, FWA services are a cost-effective alternative when the deployment of a high speed fixed broadband network is not economically feasible. Ongoing 5G network deployment alongside the development of extended 5G mmWave solutions will allow service providers to offer high speed 5G FWA services in both urban and low density areas. 5G FWA services are expected to represent 4 percent of residential broadband services in 2026, growing from less than 1 percent in 2020.

As residential broadband penetration saturates mature markets, competition among broadband operators is likely to create challenges to maintain market share. "In addition to network upgrades, broadband operators need to invest in cutting-edge software and hardware to optimize network performance and support better user experiences. Providing advanced home networking devices, internet security and home network self-diagnosis tools can help service providers reduce churn and improve average revenue per user," Lynn concluded.

PRECISION COMPONENTS. PRECISION MEASUREMENTS.



Make complex measurements where limited solutions exist

KEY FEATURES

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Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

TPC Wire & Cable, a portfolio company of **Audax Private Equity**, announced that it has completed the acquisition of **The First Electronics Corp. (FEC)**, a supplier of manufactured custom cable assemblies for military and defense applications. FEC is a supplier of electrical wiring harnesses, specializing in the production of overmolded, extra-flexible, multi-conductor, EMI-shielded cable assemblies and harnesses and electro-mechanical assemblies custom-built for military applications. TPC recently formed its Engineered Products Division to expand its coverage of high reliability end-markets like space, aerospace and defense, semiconductor, subsea, renewables and medical devices among others.

Quantic™ Electronics, a portfolio company of **Arcline Investment Management**, announced the acquisition of **BEI Precision Systems & Space Company Inc.** from J.F. Lehman & Company. BEI Precision designs, engineers and manufactures highly accurate, resilient and reliable position feedback sensors and frequency reference technologies for mission-critical space, land, air and sea applications. The company's products are designed into many of the U.S. government's highest-priority, long-life programs. Evercore served as financial advisor to Quantic.

COLLABORATIONS

Anritsu and **Bluetest** have combined their recent product upgrades to create a strong and up-to-date OTA measurement solution for verifying the WLAN RF-performance in this new 6 GHz band, as well as of existing WLAN standards (802.11 a/b/g/n/ac/ax) in the 2.4 and 5 GHz bands. The collaboration provides customers with a complete WLAN OTA test solution capable of transmit power and receiver sensitivity measurements on devices and access points.

Cadence Design Systems Inc. and **Tower Semiconductor** announced the release of a silicon-validated SP4T RF SOI switch reference design flow using the Cadence® Virtuoso® Design Platform and RF Solution. The reference design flow provides a faster path to design closure for advanced 5G wireless, wireline infrastructure and automotive IC product development. This new RF reference design flow leverages a comprehensive set of mixed-signal and RF design, simulation, system analysis and signoff tools that are tuned for Tower's CMOS, BiCMOS, SOI and SiGe process technologies.

Triad RF Systems Inc. has entered into a partnership with **Mobilicom**, an end-to-end provider of cybersecurity and smart solutions for drones, robotics and autonomous platforms. The partnership will initially provide an integrated product line featuring Mobilicom's multi-function radios (MCU product family) coupled with Triad's high-power radio solutions and create a new product line for sale and distribution by both companies. The product line will include Mobilicom's secure Mobile MESH technology and its ICE Cybersecurity Suite with Triad's smart RF amplifiers to provide the most cost effective and efficient fully integrated amplified MIMO radios, on the market, for MESH network communications.

thinkRF Corp. announced a global strategic partnership with **TMY Technology Inc.** to distribute and collaborate on the development of industry leading products to enable the deployment of 5G, 6G and advanced mmWave applications. TMYTEK, a Taiwan-based company, is an industry leader in mmWave solutions for manufacturing and research applications. This global partnership will position thinkRF and TMYTEK as one of the leading providers for the 5G, 6G and advanced mmWave applications.

EMA Design Automation®, a full-service provider and innovator of electronic design automation systems solutions, and **Digi-Key Electronics** have collaborated to release the OrCAD® Capture Bundle, a special offer available only on digikey.com. This unique collaboration furthers both EMA's and Digi-Key's goal of increasing the efficiency of engineers by providing the tools they need to streamline the design process. Now, engineers can focus on design, eliminate tedious tasks, quickly innovate and keep the design process moving forward, all within a single unified design environment.

Laird Connectivity announced a partnership with **KORE**, a leader in the IoT solutions and worldwide connectivity-as-a-service. Under this partnership, the companies plan to offer a broad portfolio of wireless IoT sensors, gateways and services that deliver wireless connectivity in remote or hard-to-reach locations. With this partnership, customers are able to leverage the combined hardware and services in a way that compresses the time to market by months.

ACHIEVEMENTS

ZTE Corp., together with the **Hangzhou Branch of China Telecom**, has conducted 300 MHz 5G QCell verification in Hangzhou Olympic Sports Center to prepare for the 19th Asian Games Hangzhou 2022 from September 10-25, 2022. During the 19th Asian Games, China Telecom, as the official sponsor of the event, is expected to guarantee high-quality telecommunications networks in the Olympic Sports Center and provide smart 5G services for 80,000 spectators. Therefore, China Telecom and ZTE have set up a dedicated Asian Games team, in charge of completing network planning and verification on site.

The **International Space Station (ISS)** has now been operational for 20 years, achieving a plethora of technological marvels. It is suited for testing the spacecraft

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systems and equipment required for possible future long-duration missions to the moon and Mars. One of those technological achievements includes continuously offering Wi-Fi services for 13 years in the pressurized module—and five years continuously outside in the vacuum of space. An exciting fifth year of external Wi-Fi® service at the ISS began in late May 2020, with a wireless LAN demonstration aboard the visiting Japanese HTV-9 cargo vehicle that arrived freighting fresh lithium-ion batteries.

Spacecom, the satellite services provider and owner-operator of the AMOS satellite fleet, and **Get SAT**, an innovator in small, lightweight satellite communication terminals for airborne, ground and maritime applications, announced the successful testing of Get SAT's next-generation Micro Sling Blade Ka-Band Satcom-On-The-Move terminal on AMOS-17's advanced, digital Ka-Band. The test was hosted at the SMS Teleport in Rugby, U.K. AMOS-17, the most advanced HTS satellite serving Africa, was chosen by Get SAT for testing its newest electronically steered antenna, bringing together optimal G/T and a high performing satellite terminal that resulted in an unparalleled throughput of 5 MBPS forward and 25 MPBS return rate.

CONTRACTS

SAIC has secured $664 million in fiscal year 2022 second quarter contract awards by space and intelligence community organizations, including a program providing digital and systems engineering solutions for intelligence and defense agencies worth $355 million. Most of these contracts serve customers in the intelligence community and classified space domain. This quarterly total also includes a previously-announced $90 million award by the **U.S. Air Force Life Cycle and Management Center, Force Protection Division** to help the U.S. Department of Defense Combatant Commands mitigate small, unmanned aircraft systems threats and protect U.S. forces.

The **U.S. Special Operations Command** has awarded **L3Harris Technologies** a five-year, $96 million IDIQ contract to procure WESCAM MX™-electro-optical, infrared and laser designator sensor suites and services. L3Harris' WESCAM MX-10D and WESCAM MX-15D sensor systems will provide multi-spectral imaging and designation capabilities for various aircraft within the U.S. Army Special Operations Aviation Command inventory. L3Harris WESCAM MX-Series products have successfully supported U.S. Army aviation programs for more than 20 years. This contract marks the second airborne sensor program win with the U.S. Army in three years. The first was a $454 million, multi-year IDIQ contract that included WESCAM MX-10D EO/IR sensor suites to support the Army's Tactical Unmanned Air Systems Shadow UAV (RQ-7Bv2) program.

Mercury Systems announced it received a $17 million order from the **U.S. Naval Air Warfare Center's Aircraft Division (NAWC-AD) for Advanced Data Transfer Systems (ADTS)** for deployment across multiple rotary-wing and tilt-rotor platforms. The ADTS, a rugged data, video and audio loader and recorder with cybersecurity capability, is used for moving mission data securely to and from the aircraft for pre- and post-mission analysis. The order is part of a firm-fixed-price, indefinite delivery/indefinite quantity contract award worth up to $84.9 million originally received in September 2020 by Physical Optics Corporation, recently acquired by Mercury Systems.

Mission Microwave Technologies, a manufacturer of highly efficient solid-state power amplifiers (SSPAs) and block upconverters (BUCs) has received follow-on orders from a government contractor to provide Ku- and Ka-Band block upconverters as components of complex satcom transportable terminals in support of the U.S. Army.

Comtech Telecommunications Corp. announced that during its fourth quarter of fiscal 2021, it was awarded multiple contracts aggregating $3.6 million from a U.S. system integrator for X-Band SSPAs and BUCs for transportable satcom terminals. Secure and available satellite communications are required to support all phases of a mission from the command center to the tactical edge.

Sarcos Defense, a wholly-owned subsidiary of **Sarcos Robotics**, and security leader **BAE Systems plc** announced that the companies are partnering to develop advanced perception and sensing capabilities for autonomous platforms for **Air Force Research Laboratory (AFRL)** to benefit DoD operations. Sarcos and BAE Systems FAST Labs™ were awarded a $1.699 million contract by AFRL to work on a collaborative sensing platform (BAA FA8750-20-S-7014).

Kumu Networks announced that it has received a $1.5 million Direct-to-Phase II Small Business Innovation Research (SBIR) project from the **U.S. Army**. The scope of the project includes integrating Kumu's Self-Interference Cancellation technology to create radios capable of not only suppressing in-band self-interference from friendly, co-located jammers but also eliminating interference from non-co-located enemy jammers, providing soldiers the ability to transmit freely to friendly forces while simultaneously jamming enemy transmissions. The Army Program of Record office plans to subsequently focus on incorporating this capability into multiple production handheld, manpack and small form-fit radios.

Robotic Research LLC announced that it was awarded this summer a SBIR Phase II contract from the **Defense Threat Reduction Agency (DTRA)**. As part of the two-year contract, Robotic Research will increase the capacity of its Pegasus Mini, the smallest of the company's transforming drone/ground robot systems, which DTRA plans to incorporate into the Modular Autonomous Counter-WMD, Increment B (MACS-B) program. Planned upgrades include changes to the airframe, battery and computing and sensing capabilities.


NEW LOOK

Around the **Circuit**

PEOPLE

▲ *Mike Conry*

Resonant, a provider of RF filter solutions developed on a robust intellectual property platform, designed to connect people and things, announced that **Mike Conry** has been appointed vice president of Product Development, with the responsibility for supporting its customers' capability to scale its XBAR technologies to commercialization and high volume manufacturing. Conry joins Resonant with a proven track record of developing new RFFE technologies and bringing them to market from invention to high volume manufacturing.

▲ *Brad Laird*

NXT Communications Corp. (NXT-COMM) announced the appointment of **Brad Laird** as vice president of engineering to oversee all aspects of technical development of NXT-COMM's electronically steerable antennas for several defense and commercial mobility applications, reporting to Carl Novello, chief technology officer. With a proven reputation as a client-facing engineer, Laird has amassed more than 21 years of hardware engineering and product development and sustainability experience.

REP APPOINTMENTS

Following last year's announcement of the acquisition of SANAV by Unictron Technologies Corp., **RFMW** and **Unictron** announced their continued distribution relationship, allowing RFMW to promote and sell the full portfolio of Unictron antenna solutions worldwide. Under the agreement, RFMW will support Unictron's antenna activity, including sales of their GPS, GNSS, UHF, Wi-Fi, 4G, 5G NR and MIMO antennas. Unictron offers both internal and external antenna solutions for applications including telematics, smart home, public safety, M2M, wearables and smart agriculture.

PLACES

Rogers Corp.'s advanced electronics solutions business will make a multi-million Euro investment at its current production site in Eschenbach, Germany. Rogers management has approved the investment to expand its proprietary metal bonding technology that is critical to support the global growth of electric vehicles (EVs) and hybrid electric vehicles (HEVs). Rogers' production area in Eschenbach will be enlarged by > 2000 m² to increase productivity and deliver the latest products. With the expansion of the production area, the production capacities for Rogers' curamik substrates will meet the future demand of the EV/HEV market.

Miniaturized Power Divider with Planar Stub Structures

R. El-Bouslemti
Ecole Nationale Polytechnique d'Oran, Algeria

F. Salah-Belkhodja
Djillali Liabes University, Algeria

Two new designs of a microstrip Wilkinson power divider feature stub structures for miniaturization. The dividers operate at 2.5 GHz and only occupy a 15.6 × 17.6 mm area. Results show good agreement between measurements and simulation, demonstrating improved performance relative to the classic design.

The field of microwaves has grown considerably over the past several years, with many telecommunications applications. This has enabled new technologies for the realization of more compact hardware with improved performance at higher operating frequencies. Waveguide transmission lines at mmWave frequencies, traditionally chosen for low dissipation losses and electrical performance, have more recently been replaced by planar structures for many applications.[1-3] Planar structures have proven to be practical because it is possible to add active or passive components on their surfaces, with the integration of passive components into the circuit a major goal for the miniaturization of future devices and systems.

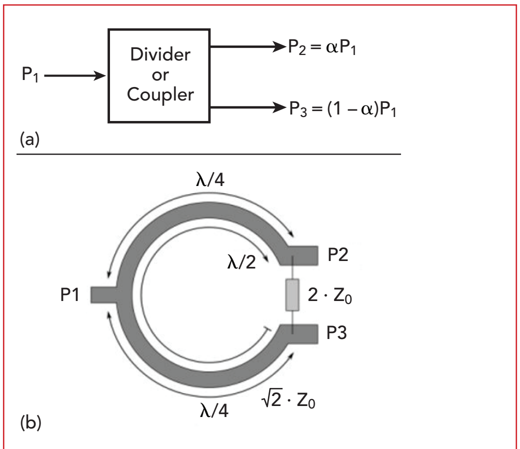

Fig. 1 **Power divider signal flow (a) and Wilkinson layout (b).**

Microstrip and stripline transmission lines have desirable properties, such as low cost, light weight, small and compact size, compatibility with integrated circuits, better reliability and good reproducibility.[3,4] The most common is microstrip,[4,5] which comprises a dielectric substrate completely metallized on one of its faces (i.e., the ground plane) and a metal strip on the other face.

The power combiner/divider is an essential element in the design of mixers and power amplifiers. Used as a divider, its role is to divide a signal at its input into several identical signals at its output. As a combiner, it adds the power of several inputs at a common output. The power divider is recipro-


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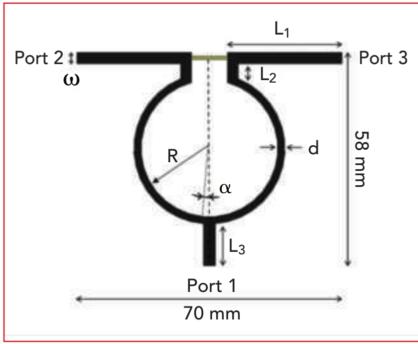


▲ Fig. 2 Classic Wilkinson power divider layout.

cal, a passive component with at least three ports: an input and two or more output ports. The output ports can be isolated, or not.[4]

The main advantages of a planar power divider are ease of integration with other technologies and the ability to withstand relatively high power levels. The planar nature of its construction supports bulk processing, enabling inherently low manufacturing costs. It exhibits good port-to-port isolation with moderate losses. One disadvantage is a quarter-wavelength (λ/4) transmission line is normally required in the design.

The most popular power divider/combiner structure is the Wilkinson (see ***Figure 1***).[4] It is composed of an input port matched to a characteristic impedance Z_0, two λ/4 lines of characteristic impedance $Z=\sqrt{2}Z_0$ and two outputs matched to Z_0. A resistance $R=2Z_0$ is connected between the two output ports to handle an output power imbalance.[5] Different techniques have been described over the years to reduce the size of the classic Wilkinson architecture, including the use of planar artificial transmission lines,[6] defected ground structures,[7] fractal structures,[8] capacitive loading,[9] lumped elements[10] and stubs.[11-13] In this work, new power divider designs using stubs are introduced to reduce the size of the classic Wilkinson structure.

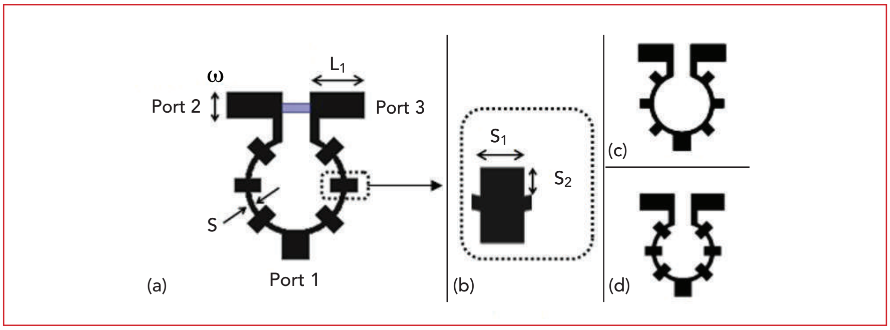
MICROSTRIP POWER DIVIDER DESIGN

The classic Wilkinson power divider is a single microstrip line on a dielectric substrate (see ***Figure 2***). The proposed microstrip power divider with stubs is shown in ***Figure 3***.

Several parameters characterize the microstrip transmission line and power divider performance. Assuming a quasi-TEM mode of propagation,[14] the phase velocity in microstrip is given by:

$$V_p = \frac{C}{\sqrt{\varepsilon_{eff}}} \quad (1)$$

where c is the speed of light and ε_{eff} is the effective relative permittivity, which is typically 2.9 for microstrip



▲ Fig. 3 Microstrip power divider with stubs (a), stub unit cell (b), power divider with open-ended stubs (c) and power divider with cross-ended stubs (d).

TABLE 1

POWER DIVIDER COMPARISON

Power Divider	L_1 (mm)	L_2 (mm)	L_3 (mm)	d ~ S (mm)	S_1 (mm)	S_2 (mm)	W (mm)
Classic Wilkinson	30.3	5	11.5	1.5	—	—	3
This Work	5	—	—	0.6	1.6	1.2	3

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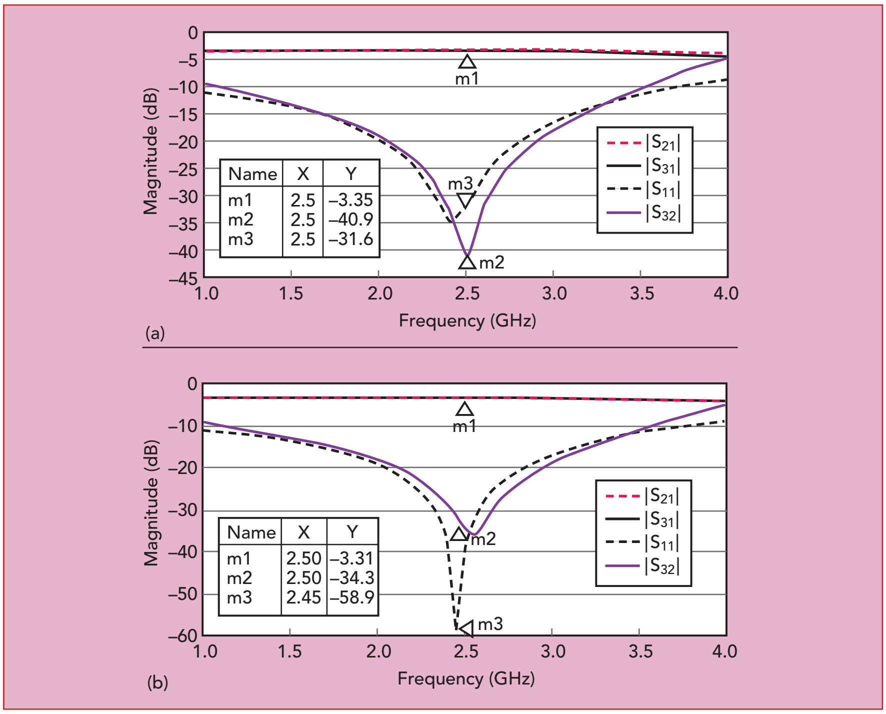
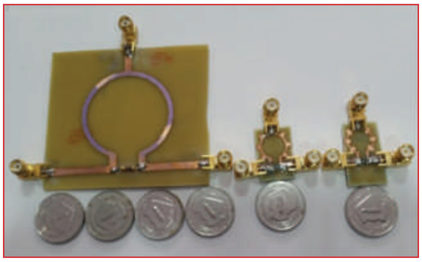


▲ **Fig. 4** Simulated power divider frequency responses with open-ended (a) and cross-ended (b) stubs.



▲ **Fig. 5** Classic Wilkinson power divider (left) vs. 2.5 GHz stub-loaded power dividers (right).

lines.[15] The characteristic impedance of the transmission line, Z_0, is given by:[14]

$$Z_0 = \frac{120\pi / \sqrt{\varepsilon_{eff}}}{W/h + 1.393 + 0.667\ln(W/h + 1.444)} \quad (2)$$

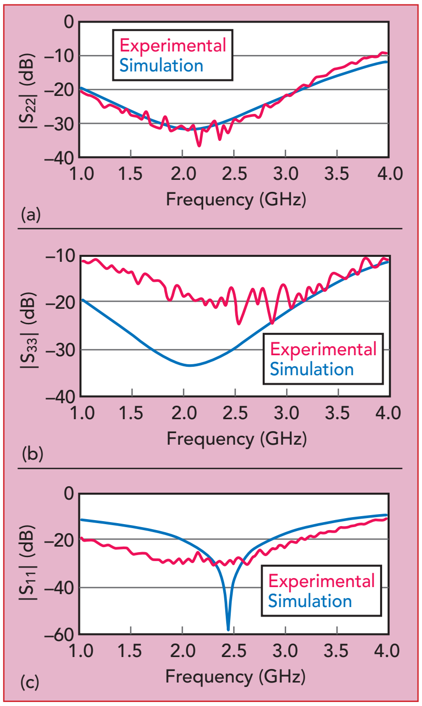
for $W/h \geq 1$, where W is width of the conducting line (see Figure 3), and h is the height of dielectric substrate.

In microstrip, only the dominant (i.e., quasi-TEM) mode propagates. Surface waves are undesirable, as they couple with the quasi-TEM mode. They become significant only at the frequency f_s, where:[2]

$$f_s = \frac{C.\tan(\varepsilon_r)^{-1}}{\sqrt{2}.\pi.h\sqrt{\varepsilon_r{}^{-1}}} \quad (3)$$

Higher-order mode excitation is avoided by operating at a frequency lower than the cutoff frequency of the first higher-order mode, which is given by:[16]

$$f_c = \frac{C}{\sqrt{\varepsilon_r}\,(2W + 0.8h)} \quad (4)$$



▲ **Fig. 6** Measured vs. simulated reflection performance of the prototype open-stub power divider: $|S_{22}|$ (a), $|S_{33}|$ (b) and $|S_{11}|$ (c).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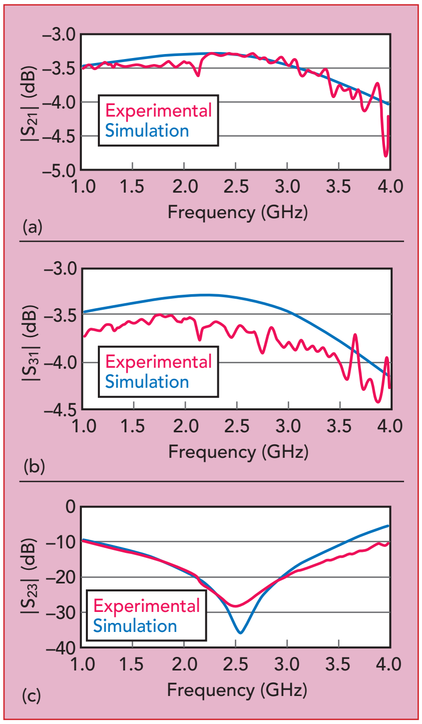

Fig. 7 Measured vs. simulated transmission performance of the prototype open-stub power divider: $|S_{21}|$ (a), $|S_{31}|$ (b) and $|S_{23}|$ (c).

In practice, the operating frequency of a microstrip line is given by:[14]

$$f_c < \mathrm{Min}\left(f_s, f_c\right) \quad (5)$$

and is calculated by:

$$f_c(\mathrm{GHz}) = 0.3\sqrt{\frac{Z_0}{1-h\sqrt{\varepsilon_r}}}\,(h \text{ in cm}) \quad (6)$$

FINAL DESIGN PARAMETERS AND SIMULATION

Figure 3 shows the planar design of the prototype dividers. It is a half tri-plate circulator structure[17] with planar input/output ports. One of the objectives of this work is to achieve a characteristic impedance at the input/output ports close to 50 Ω. The width W of the input/output lines according to the coupling angle and the center circle radius are as follows:

$$W = 2R\sin\alpha \quad (7)$$

The width of the input/output port lines are adjusted to W = 3 mm to achieve a characteristic impedance of 50 Ω. The parameters in ***Table 1*** are optimized using Ansoft HFSS, and the simulation results of the two power divider designs are shown in ***Figure 4***.

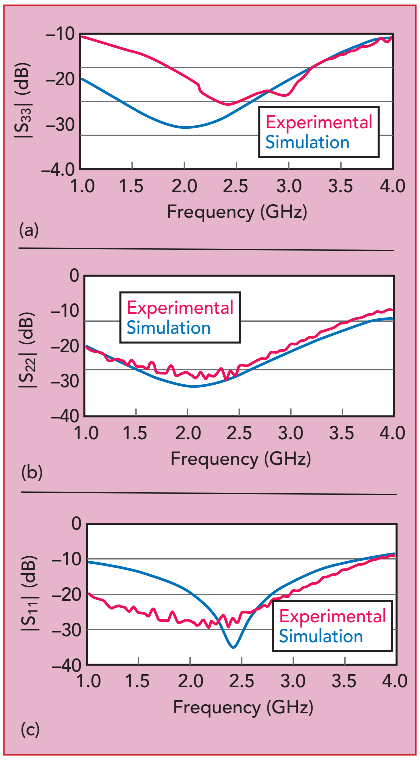

Fig. 8 Measured vs. simulated reflection performance of the prototype cross-stub power divider: $|S_{33}|$ (a), $|S_{22}|$ (b) and $|S_{11}|$ (c).

The prototype power dividers are easy to fabricate; and they occupy areas of only 15.6 × 18.8 mm and 15.6 × 17.6 mm, respectively, which is about a 93 percent size reduction compared with the classic Wilkinson power divider.

EXPERIMENTAL RESULTS

The prototype powers dividers were fabricated on an FR4 substrate (ε_r = 4.5, h = 1.6 mm). ***Figure 5*** shows the fabricated prototypes alongside a conventional Wilkinson power divider. A surface mount resistor was placed between the two output ports for improved isolation. A Keysight E5071C network analyzer was used for the measurements, and ***Figures 6–9*** compare the measured and simulated performance, which are in good agreement. Little difference was observed in the measured performance of the two prototypes. At the operating frequencies, $|S_{21}|$ and $|S_{31}|$ were around -3.4 dB for both. $|S_{11}|$ was -25.75 dB for the divider with the open stubs and -27.64 dB for the divider with cross stubs. Coupling between the output ports, $|S_{23}|$, was -26.35 dB for the divider with open stubs and -28.25 dB for the divider with cross stubs. ***Figure 10*** shows the measured phase difference between the prototype dividers' output ports. The output phase difference over the operational frequency range of 2.5 GHz is 0 degrees.

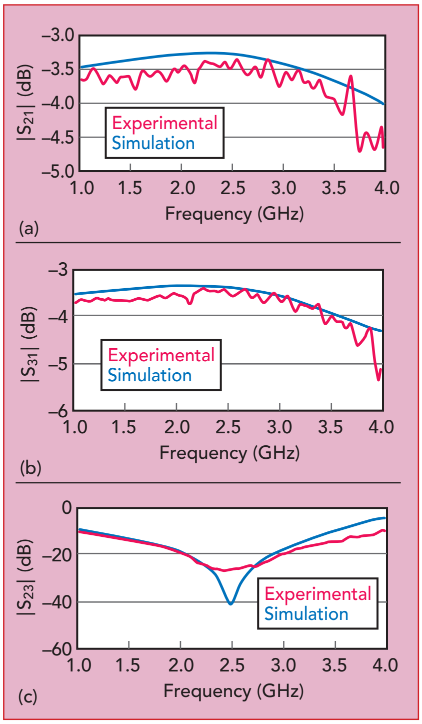

Fig. 9 Measured vs. simulated transmission performance of the prototype cross-stub power divider: $|S_{21}|$ (a), $|S_{31}|$ (b) and $|S_{23}|$ (c).

The measured versus simulated performance of the classic Wilkinson power divider is shown in ***Figure 11***. The isolation performance

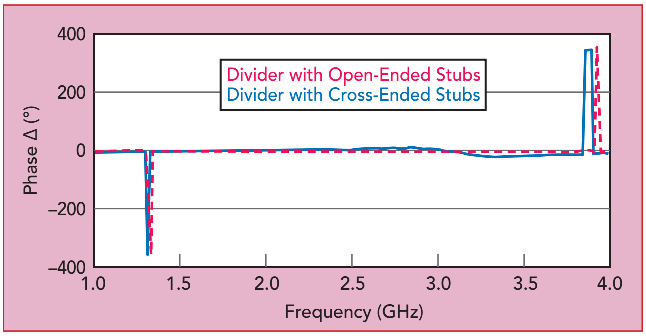

Fig. 10 Phase difference between the port 2 and 3 outputs for the prototype power dividers.

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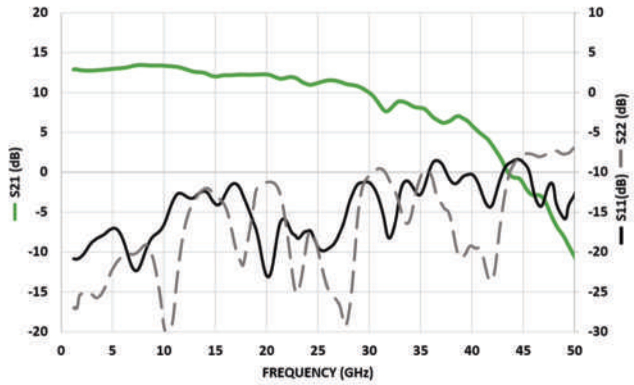

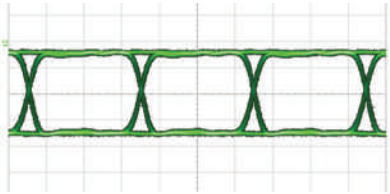

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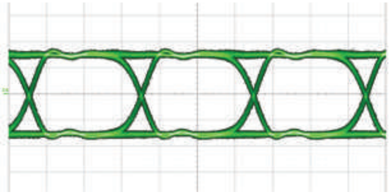

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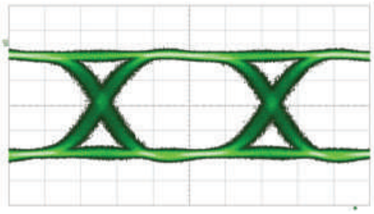
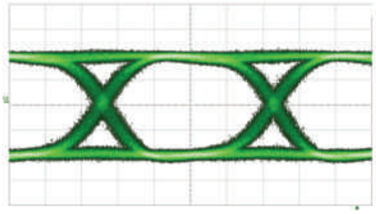


INPUT: 32 GBPS PRBS31



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of the stub designs represents a 20 dB improvement relative to the classic Wilkinson (see ***Figure 12***). The input and output reflection characteristics ($|S_{11}|$, $|S_{22}|$ and $|S_{33}|$) are optimized, while $|S_{21}|$ and $|S_{31}|$ approach the ideal value of 3 dB.

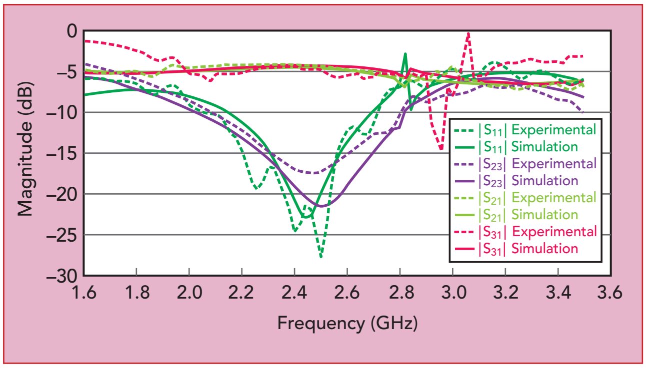

Fig. 11 Measured vs. simulated $|S_{xx}|$ of the classic Wilkinson power divider.

CONCLUSION

A novel version of a Wilkinson power divider uses a compact stub structure to achieve a 93 percent size reduction. The performance of two slightly different prototype designs agrees closely with the simulations and without compromise relative to the classic design. Actually, output port isolation is improved by 20 dB.■

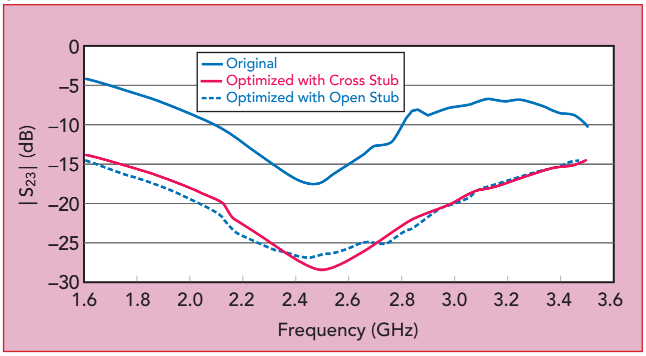

Fig. 12 $|S_{23}|$ of the original, cross-stub and open-stub power dividers.

ACKNOWLEDGMENT

This work was supported by the Directorate General for Scientific Research and Technological development (DGRSDT) of Algeria.

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A Steering Antenna for Long-Reach mmWave X-Haul Links

M. Oldoni, S. Moscato, G. Biscevic and G. Solazzi
SIAE Microelettronica, Milan, Italy

With the evolution of LTE and the launch of 5G, the need for high capacity backhaul has become essential in mobile networks, due to the colocation of nodes, higher numbers of sectors and higher node coverage. Densification has reduced the distances between nodes, so much that over 50 percent of the nodes in a network are located less than 5 km apart (see ***Figure 1***). Globally, more than 60 percent of base stations are connected with microwave radio links. The traditional frequency bands offer a limited and often noncontiguous addressable spectrum, capping the transport capacity. Moving up in frequency, however, offers larger spectrum bands.[1]

The E-Band allocation, from 71 to 76 and 81 to 86 GHz, offers 10 GHz total bandwidth, yet a shorter hop length because of path loss. From Friis' formula, the higher the frequency, the more a radio signal is attenuated by propagation:

$$\text{Attenuation}_{dB} = 20\log_{10}\frac{4\cdot\pi\cdot\text{length}_m\cdot\text{frequency}_{Hz}}{c_{m/s}} \quad (1)$$

where c denotes the speed of light in air, approximately 3×10^8 m/s. An 80 GHz communication link has 20 dB more attenuation than an 8 GHz link of the same length. Currently, E-Band radios have propagation behaviour similar to a traditional licensed microwave radio with a hop length comparable to that of a 38 or 42 GHz band. A 38 GHz link can achieve 2 Gbps capacity using a complex 4096-QAM modulation over a 224 MHz channel, which is the largest channel available in the traditional licensed microwave bands. In contrast, E-Band radios can reach 10 Gbps transport capacity over 2 GHz channels with much simpler 128-QAM.

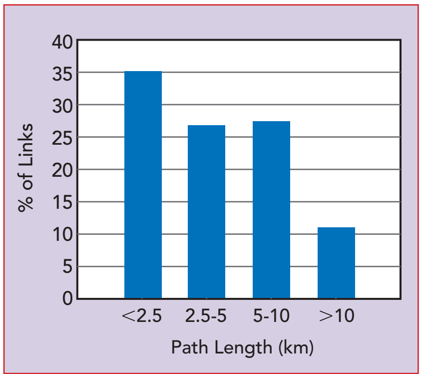


Fig. 1 Distribution of backhaul link distances for a European mobile operator.

Using E-Band boosts the mobile infrastructure capacity 5×, which will satisfy 5G transport needs. This increase has driven the adoption of E-Band, one of the top three frequency bands deployed globally in 2020.

ANTENNA CHALLENGES

Typically, a Cassegrain parabolic antenna is used for point-to-point backhaul radio links (see ***Figure 2a***). It is one of the simplest ways to use a large radiating area and focus the beam to a specific direction, which yields

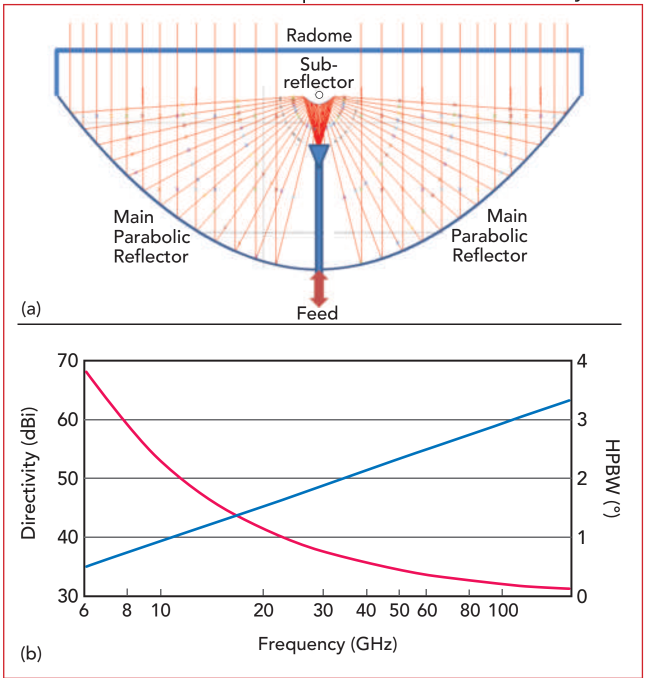


Fig. 2 Cassegrain double-reflector antenna (a). Theoretical directivity and total HPBW of a three-foot parabolic antenna (b).

higher antenna gain.[2] The directivity of the antenna is given by:

$$\text{Directivity}_{dB} = 10\log_{10} \frac{\text{efficiency} \cdot 4 \cdot \pi \cdot \text{Area}_{m^2} \cdot (\text{frequency}_{Hz})^2}{(C_{m/s})^2} \quad (2)$$

where the efficiency is usually around 0.7.

The higher the transmission frequency, the more directive the antenna beam becomes, as shown in ***Figure 2b***.[3] However, these narrower half-power beamwidths (HPBW) present a challenge for antenna alignment, which is exacerbated as the antenna diameter increases. A link is susceptible to misalignment, which can lead to signal deterioration and outages, reducing link availability. After the initial setup, misalignment can be caused by the sway of the mount in windy conditions and the twist of the mounting pole as it expands and contracts with daily changes in temperature.

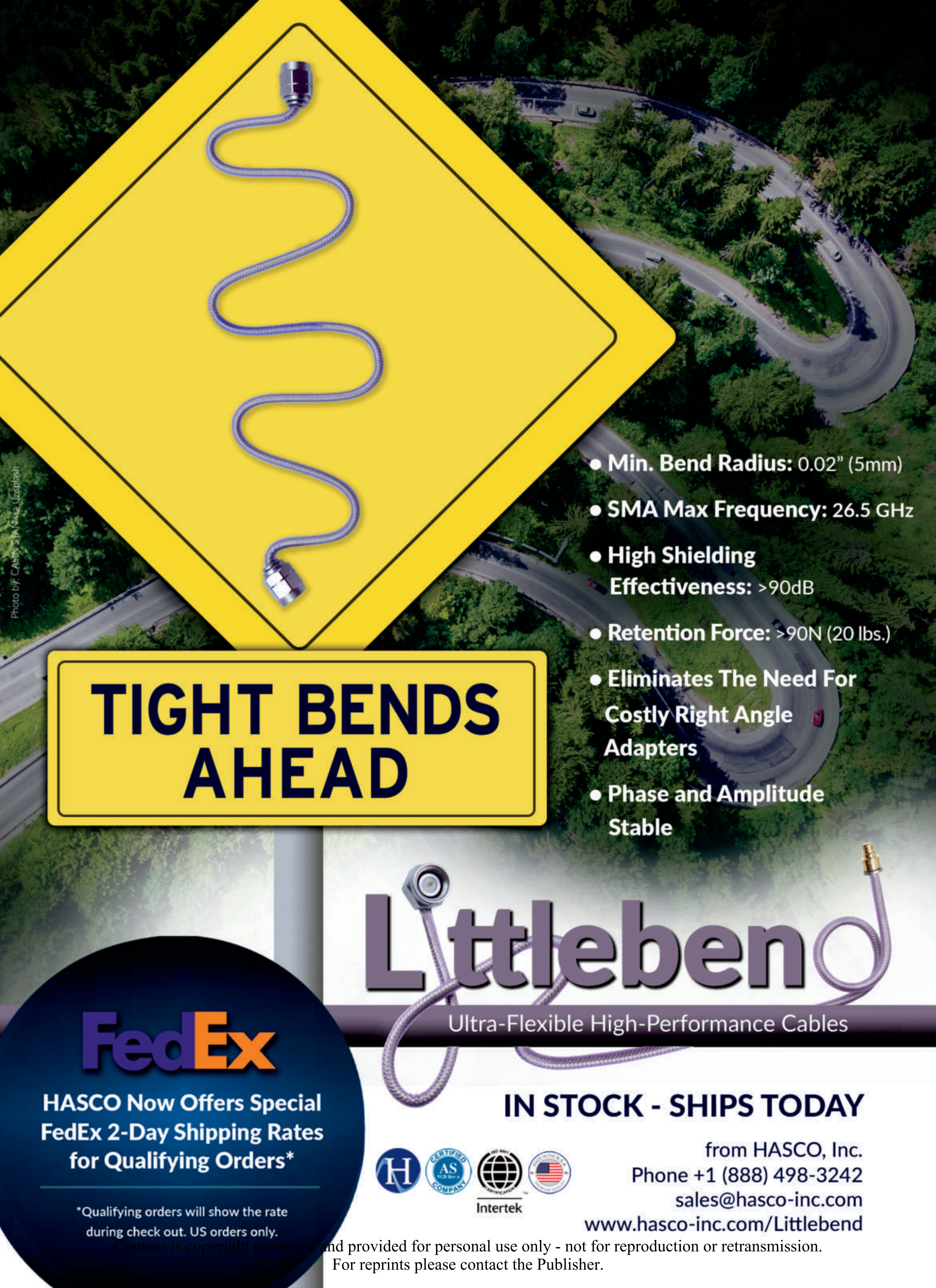
Today, 80 GHz links mainly use antennas 1 foot (0.3 m) in diameter and have directivity of approximately 45 dBi. Replacing them with three-foot (0.9 m) antennas would increase the directivity to 54 dBi, an additional 2 × 9 dB combining the gains from the two antennas forming the link. This improvement doubles the hop length. However, the higher gain of the three-foot antennas increases the directivity of the beam and the requirement for tight angular alignment. Misalignment becomes critical, to the point of being practically unbearable: a one-foot antenna at 80 GHz has a HPBW of about ±0.5 degrees around boresight, while the HPBW of a three-foot antenna is only ±0.15 degrees.

A steering antenna can counteract environmental changes and maintain alignment, guaranteeing link availability and enabling the use of larger antenna sizes and longer hops. Both will aid the commercial adoption of multi-Gbps wireless transport.

MISALIGNMENT

Three environmental phenomena affect antenna alignment: wind vibration, wind plastic deformation and thermal deformation. The first, wind vibration can be addressed by proper site design. Since the effect of wind is a sway proportional to gust speed, plastic deformation can be modeled using the statistical distribution of wind speed in most urban and rural areas. The average effect is deemed negligible and no longer considered.

The remaining phenomenon to hinder radio link performance with highly directive beams is the thermal deformation of the tower mast holding the antenna. Daily sun heating occurs predominantly with clear skies. Standard monopoles bend from 0.3 to 0.6 degrees because of the temperature difference between the side of the monopole heated by the sun and the opposite side. Structures other than monopoles, such as lattice towers and buildings, are usually less prone to this effect;



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however, requiring that two- and three-foot E-Band antennas be mounted to specific rigid structures is not an acceptable constraint.

EMBS ANTENNA

Since the daily thermal change is slow and limited in angle, an electromechanical beam steering (EMBS) antenna can compensate for the thermal behavior. Using a simplified model for a parabolic dish without a sub-reflector,[4] the limited angular tilt, θ, of the beam from boresight is introduced by offsetting the focus, δ, on its plane:

$$\sin(\theta) = \frac{\delta_m}{FocalLength_m} \left(1 + 0.34\left(\frac{Diameter_m}{4 \cdot FocalLength_m}\right)^2\right) / \left(1 + \left(\frac{Diameter_m}{4 \cdot FocalLength_m}\right)^2\right) \quad (3)$$

Scan loss in the far field translates to a gain loss as a function of steering angle; hence, scan loss is the figure determining the practical applicability of a steering antenna. Simulations characterizing the scan loss show the EMBS antenna design has under 3 dB scan loss at 2 degrees, which is acceptable since monopoles are expected to deform less than ±1 degree.

Using actuators to offset and rotate the sub-reflector in a Cassegrain antenna is equivalent to a steering mechanism and easier to implement, so it was chosen for the EMBS design. In a basic yet effective form, the tracking algorithm in the antenna control system monitors the received power signal and drives the actuators, altering the sub-reflector configuration to maintain correct alignment. The received signal strength indication signal is used since it is available at the outdoor unit (ODU). With most commercial E-Band radio systems, no other connections are required, which keeps the antenna and ODU as separate entities.

TESTING THE CONCEPT

To validate the EMBS concept, an open test range was set up using a 210 m link between SIAE Microelettronica's laboratory rooftop and a tower site with a monopole structure. A standard one-foot antenna was installed on the tower, and a three-foot EMBS prototype was installed on the rooftop (see ***Figure 3***). The E-Band prototype antenna included an actuator and control system to change its alignment with the antenna on the tower.

Initially, the EMBS antenna was set up as a standard three-foot antenna, with the actuator locked to its nominal position, making the beam coincident with the antenna's axis. The antenna orientation was set by adjusting the antenna's coarse and fine alignment screws, noting the received power as the reference power level. Once peak alignment was achieved, the three-foot antenna

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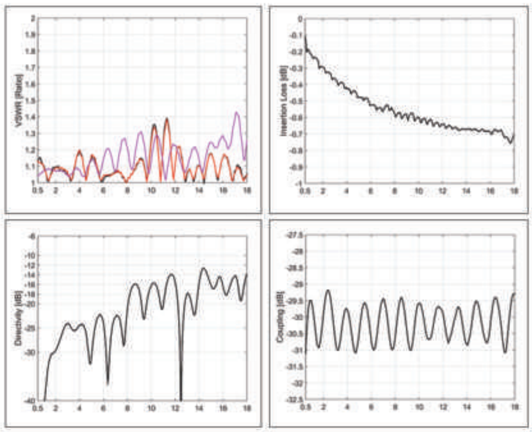

Frequency Range (GHz)	P/N	Coupling Max.(dB)	Main Line VSWR Max.(:1)	Coupling VSWR Max.(:1)	Insertion Loss* Max.(dB)	Flatness Max.(dB)	Directivity Min.(dB)	Power Max.(W)	Unit Price** (USD)
0.5-6	D30H005060	30±0.7	1.3	1.3	0.6	±1	15	600	1276
	D40H005060	40±0.8	1.3	1.3	0.6	±1.1	15	600	1276
0.5-18	D30H005180	30±1.2	1.5	1.6	1	±1.2	10	400	1899
	D40H005180	40±1.2	1.5	1.6	1	±1.4	10	400	1899
0.7-6	D30H007060	30±0.7	1.3	1.3	0.5	±0.9	15	600	1195
	D40H007060	40±0.7	1.3	1.3	0.5	±0.9	15	600	1195
1-6	D30H010060	30±0.7	1.3	1.3	0.5	±0.9	15	600	1073
	D40H010060	40±0.7	1.3	1.3	0.5	±0.9	15	600	1073
1-18	D30H010180	30±1.2	1.5	1.6	0.8	±1	10	400	1417
	D40H010180	40±1.2	1.5	1.6	0.8	±1	10	400	1417
2-6	D30H020060	30±0.7	1.3	1.3	0.4	±0.7	15	600	931
	D40H020060	40±0.7	1.3	1.3	0.4	±0.7	15	600	931
2-8	D30H020080	30±0.8	1.4	1.4	0.4	±0.7	14	600	1033
	D40H020080	40±0.8	1.4	1.4	0.4	±0.7	14	600	1033
2-18	D30H020180	30±1.0	1.5	1.6	0.6	±0.8	10	400	1215
	D40H020180	40±1.0	1.5	1.6	0.6	±0.8	10	400	1215
6-18	D30H060180	30±1.0	1.5	1.6	0.5	±0.7	10	400	972
	D40H060180	40±1.0	1.5	1.6	0.5	±0.7	10	400	972

* Theoretical I.L. Included
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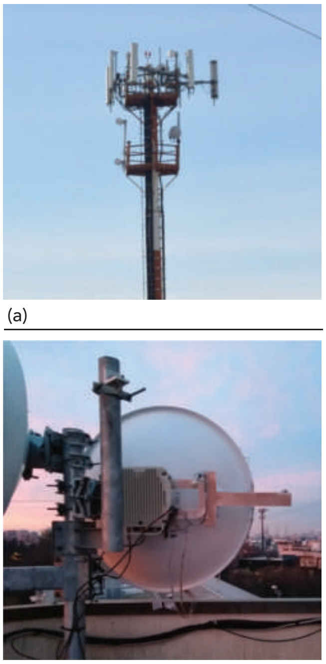
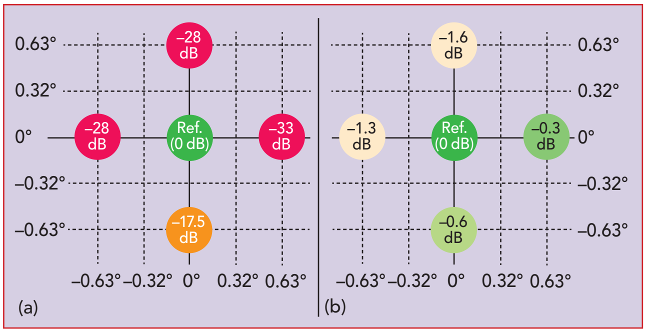


▲ Fig. 3 Test range comprising a typical 30 m high monopole for telecom backhauling (a) and three-foot EMBS prototype antenna (b).

was misaligned by about 0.63 degrees, leading to a significant power loss (see ***Figure 4***). The measurements agree with theory, which projects approximately 20 dB loss from the aligned reference value. The manual misalignment was repeated in all four directions to mimic severe monopole thermal deformation with a standard three-foot antenna. Next, the EMBS antenna actuators were enabled and used to maximize the received power after the same manual misalignment in the four directions. The relative power loss was measured and is also shown in Figure 4.

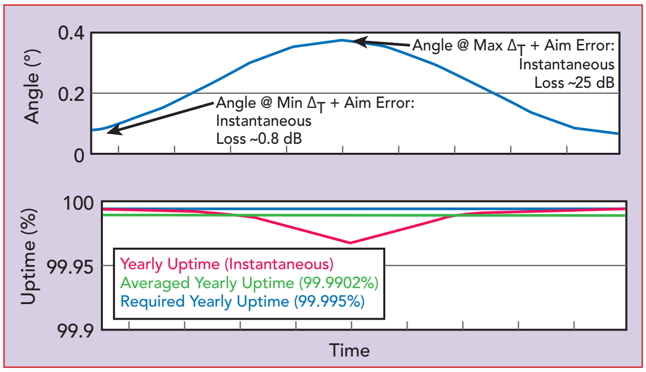


▲ Fig. 4 Power loss caused by antenna misalignment (a); improvement achieved with EMBS (b).

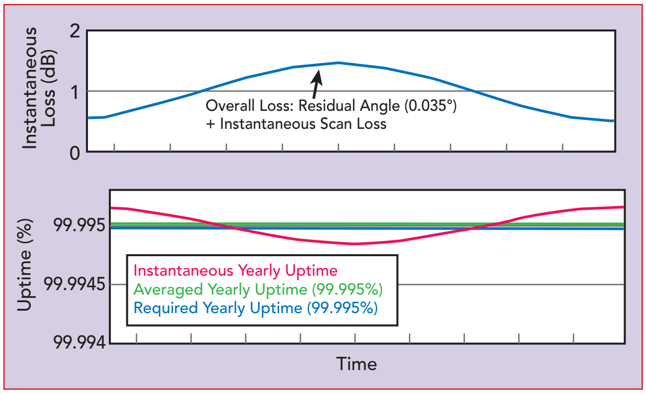
The measured loss levels with the active EMBS antenna show that the EMBS solution provides an effective way to counter monopole deformation, which would otherwise degrade link performance.

To show the effectiveness of the EMBS antenna in the field, SIAE Microelettronica developed a model for thermal deformation to simulate a 3.5 km link using three-foot antennas. The link was planned using standard point-to-point margins and alignment errors, designed to meet 99.995 percent availability operating at 400 Mbps throughput (4-QAM using a 2 GHz channel with reduced bandwidth) and 99.95 percent availability at 10 Gbps throughput (128-QAM using a 2 GHz channel bandwidth). The worst case scenario for the two sites occurs when the structures tilt in opposite directions, resulting in the largest loss. ***Figure 5*** shows the simulated performance over 24 hours for a link using standard antennas. Incorporating minor seasonal variations to extending this over a full year, the expected link availability drops to 99.990 percent at 400 Mbps and 96 percent at 10 Gbps. This means 35 hours per year of lower capacity, which is unacceptable for mobile applications. The 22 dB loss is greater than the 9 + 9 dB added gain from using three-foot antennas instead of one-foot antennas.

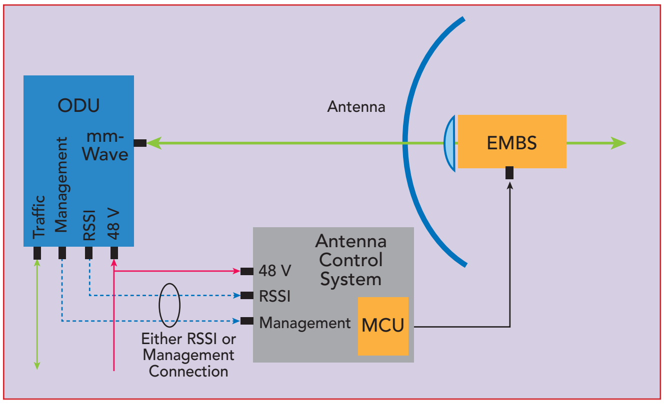
With the same assumptions, ***Figure 6*** shows the expected performance with the EMBS antenna compensating for deformations due to heating, including residual misalignment and realistic scan losses. Including a small 1 dB equivalent loss, the link's uptime over a year meets the required 99.995 percent availability at 400 Mbps and the availability of a 10 Gbps link is 99.95 percent. An EMBS system with the performance demonstrated in this field experiment can overcome thermal deformations of monopoles, enabling the use of higher gain antennas for long-reach mmWave links.



▲ Fig. 5 Simulated instantaneous uptime over 24 hours for the standard three-foot antenna.



▲ Fig. 6 Simulated instantaneous uptime over 24 hours for a 3.5 km link using three-foot antennas equipped with EMBS.



▲ Fig. 7 Connecting the EMBS antenna (antenna control system, actuators and antenna) to the ODU.

CONCLUSION

Larger antenna sizes at 80 GHz can enable higher capacity and low latency point-to-point links for mobile and other wireless transport applications such as 5G. However, the standard high directivity antennas have drawbacks from misalignment and thermal deformations, which will severely limit their usage, as predicted by simulations and confirmed by measurements. An EMBS approach, as described in this article, counters thermal misalignment and enables use of high directivity antennas, i.e., 2 ft and greater. The prototype three-foot EMBS antenna achieved low static and scan loss, i.e., approximately 1 dB at 0.63 degrees off boresight. Tracking to counter misalignment can be driven by the radio equipment or the antenna controller (see ***Figure 7***).

While the solution described here only uses information from the local site, more effective tracking might be achieved if the control algorithm coordinates information from both the local and remote sites to align both local and remote antennas. To coordinate the remote site, the ODU could send transmit power adjustment signals to counteract fading, preventing unnecessary antenna movement. Also, an ODU with MEMS devices could provide tilt direction indications for a faster reaction of the first movement. ■

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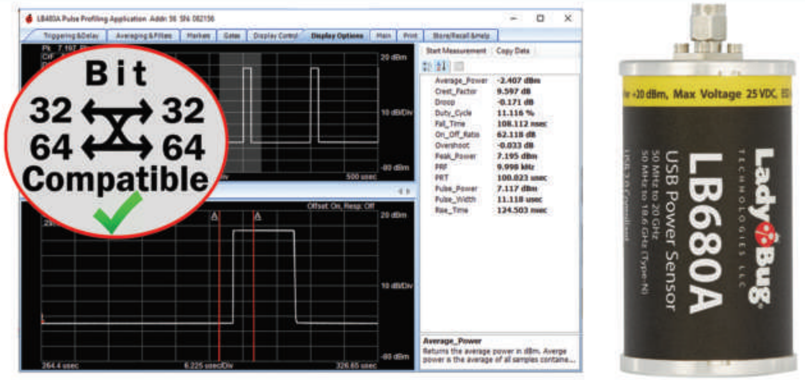


Microstrip Branch-Line Coupler with Compact Size and Wideband Harmonic Suppression

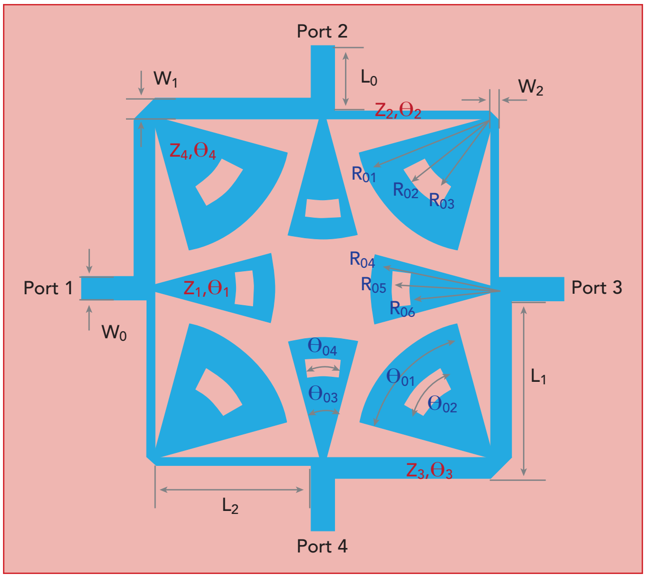
Kae-Oh Sun and Hai Zhang
University of Wisconsin, Madison, Wis.

A new microstrip branch-line coupler with compact size and wideband harmonic suppression uses modified radial stub loaded resonators. The new structure not only reduces the occupied area to 14.8 percent of a conventional branch-line coupler at 580 MHz, it also has high eleventh harmonic suppression. A fractional bandwidth greater than 5.2 percent is achieved while the phase difference between S_{21} and S_{31} is within 90 ± 1.0 degrees. The measured fractional bandwidths of $|S_{21}|$ and $|S_{31}|$ within 3 ± 0.5 dB are 24.1 and 24.2 percent, respectively, while insertion loss is comparable to that of a conventional branch-line coupler.

Branch-line couplers are widely used in microwave applications such as mixers, power amplifiers and frequency multipliers. They have two drawbacks: first, because the conventional branch-line coupler is composed of four quarter-wavelength (λ/4) transmission line sections at the designed frequency, it occupies a large area, especially at low frequencies. Second, the conventional design has harmonics at integral multiples of the fundamental operating frequency.

Much work has been reported in recent years to achieve both a compact design and harmonic suppression.[1-16] Usually, there are two methods, the first is to load the coupler with shunt open stubs. With shunt open stubs inside the free area of the branch-line coupler, Eccleston and Onga[4] reported a size reduction of 37 percent compared to a conventional design at 1.8 GHz. Based on a similar idea, Mondal and Chakrabarty[5] described a branch-line coupler with a 42 percent size reduction at 2.4 GHz, including fifth harmonic suppression. The second design method is to introduce slow-wave resonators in the coupler structure. Using compensated spiral compact microstrip resonant cells, Gu and Sun[6] described a branch-line coupler with its area reduced to 24 percent of a conventional design with second and third harmonic suppression at 2.4 GHz. However, the isolation was not ideal. By introducing high-low impedance resonators inside the free area of the coupler, Wang et al.[7] proposed a slow-wave branch-line coupler with its area reduced to 28 percent of a conventional design at 2.0 GHz, but with only second harmonic suppression. While other methods[8-16] achieved compact size, they need improvement to suppress harmonics.

In this work, a new microstrip branch-line coupler with compact size and wideband harmonic suppression is described. It uses modified radial stub loaded resonators based on our previous work.[17] A 580 MHz branch-line coupler was designed, fabricated and measured. It reduced the occupied area to 14.8 percent of a conventional design at the same frequency and also has high eleventh harmonic suppression. Its fractional bandwidth is greater than 5.2 percent, while

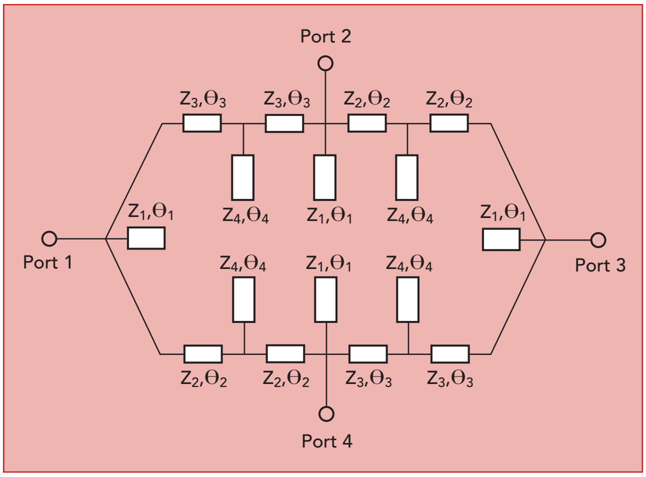


▲ Fig. 1 Branch-line coupler layout.

the phase difference between S_{21} and S_{31} is within 90 ± 1.0 degree.

CIRCUIT DESIGN

The topology of the design comprises eight modified radial stubs loaded inside the free area of a conventional branch-line coupler (see ***Figures 1*** and ***2***). Each stub is composed of a short high impedance line and a



▲ Fig. 2 Branch-line coupler equivalent circuit.

long, radial, low impedance line. The length of the high impedance line is very short, less than λ/10, where λ is the guided wavelength at the operating frequency.

Each high impedance line can be considered a lumped element with a negligibly small value, and its inductance effect on the main transmission lines between two adjacent ports can be ignored. The capacitance caused by the low impedance lines is distributed in parallel with the main transmission lines. This increases the per unit length capacitance of the main transmission lines between two adjacent ports. An increased propa-


5G

gation constant means a shorter physical structure can be used to yield the required electrical length compared with a conventional transmission line. This new type of slow-wave loading does not increase the circuit area, as the periodic slow-wave loading is located inside the branch-line coupler. A desired slow-wave factor is achieved by properly adjusting the structure parameters. When the electrical length of the loaded high-low impedance resonator is an odd multiple of $\lambda/4$, where λ is the guided wavelength at the spurious resonance frequency, harmonic signals that occur at the integral multiples of the fundamental are suppressed.

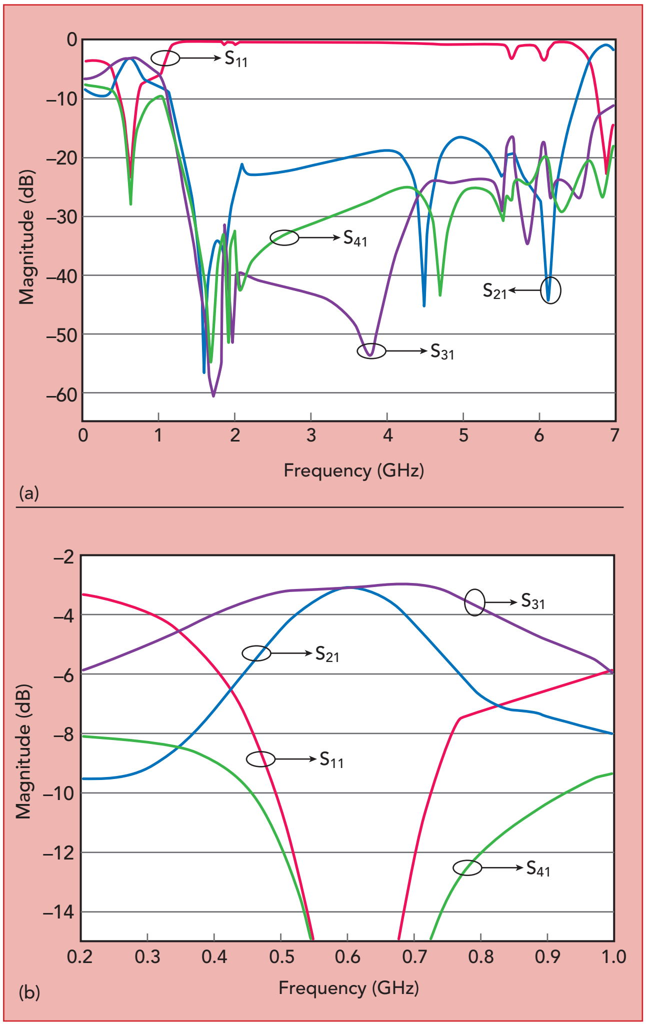
After optimization using full-wave electromagnetic simulation software, the final parameters of the branch-line coupler are: W_0 = 1.70 mm, W_1 = 1.56 mm, W_2 = 0.57 mm, L_0 = 5.0 mm, L_1 = 13.7 mm, L_2 = 12.1 mm, R_{01} = 10.5 mm, R_{02} = 8.0 mm, R_{03} = 6.0 mm, R_{04} = 10.0 mm, R_{05} = 8.5 mm, R_{06} = 7.0 mm, θ_{01} = 60 degrees, θ_{02} = 30 degrees, θ_{03} = 30 degrees and θ_{03} = 18 degrees. These dimensions can be easily implemented with standard printed circuit board etching processes. The substrate used has a relative dielectric constant of 2.94, a thickness of 0.76 mm and the total area of the branch-line coupler is 590.2 mm^2.

SIMULATION AND MEASUREMENT

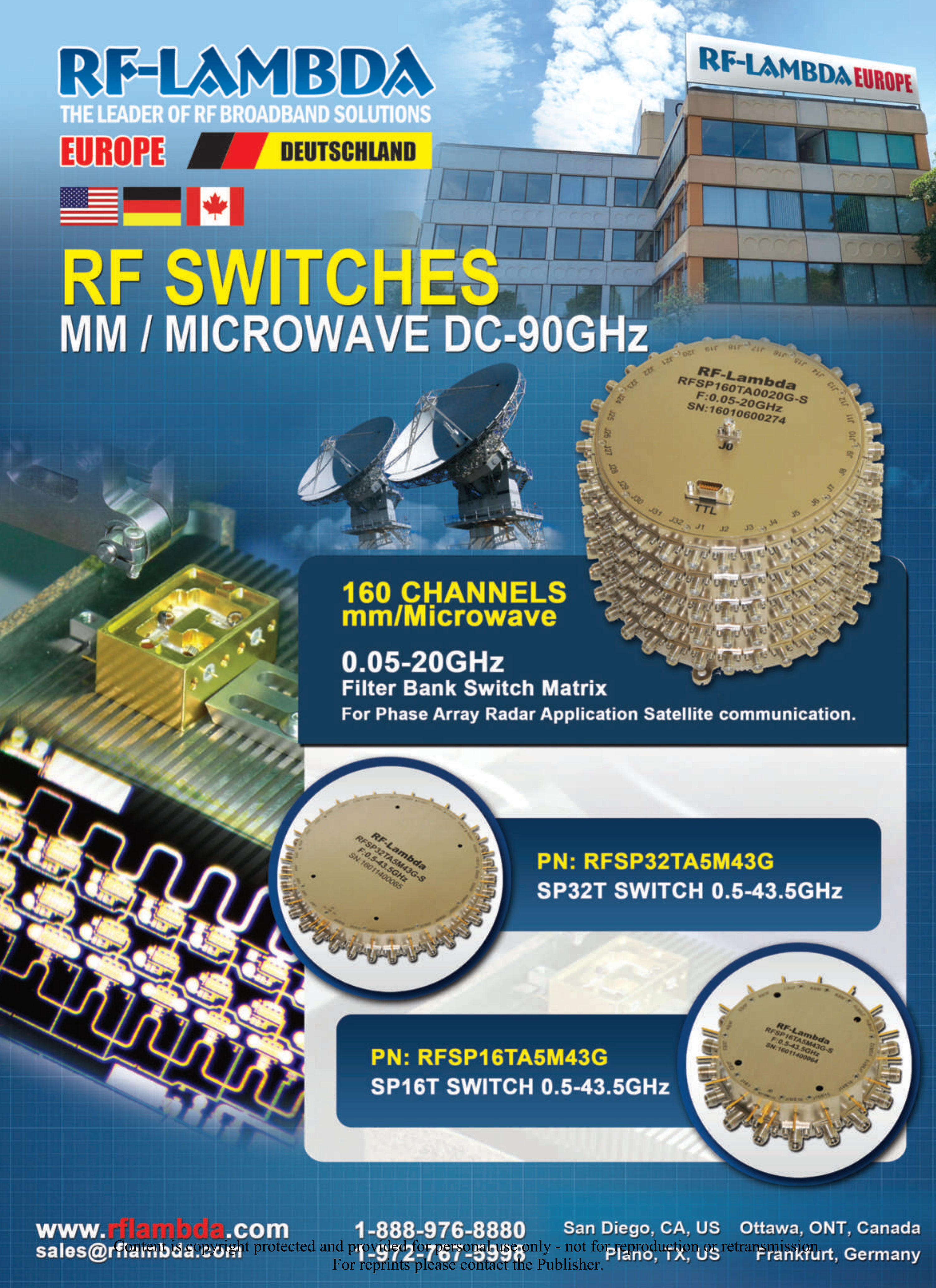
Simulation was performed using ANSOFT HFSS 13.0, and the predicted performance is shown in ***Figure 3***. Measurements made with a Keysight Technologies 8531B network analyzer (see ***Figure 4***) show a center frequency at 580 MHz with $|S_{21}|$ and $|S_{31}|$ = -3.0 dB. For $|S_{21}|$ and $|S_{31}|$ within -3 ± 0.5 dB, the measured fractional bandwidths are 24.1 and 24.2 percent, respectively. ***Figure 5*** shows the phase difference between S_{21} and S_{31}. With a criterion of ±1 degree around the nominal 90-degree phase difference, the frequency range is 570 to 600 MHz, corresponding to a bandwidth of 5.2 percent.

Figure 4a shows that eleventh harmonic signals are effectively suppressed with $|S_{21}|$ and $|S_{31}|$ below -10 dB. This means the new coupler will protect any following circuitry from interference from 1.1 to 6.5 GHz, such as from the IEEE 802.11 a/b/g standard.

The circuit area of a conventional branch-line coupler at the same frequency is approximately 3900



▲ **Fig. 3** Simulated $|S_{xx}|$ from DC to 7.0 GHz (a) and 0.2 to 1.0 GHz (b).



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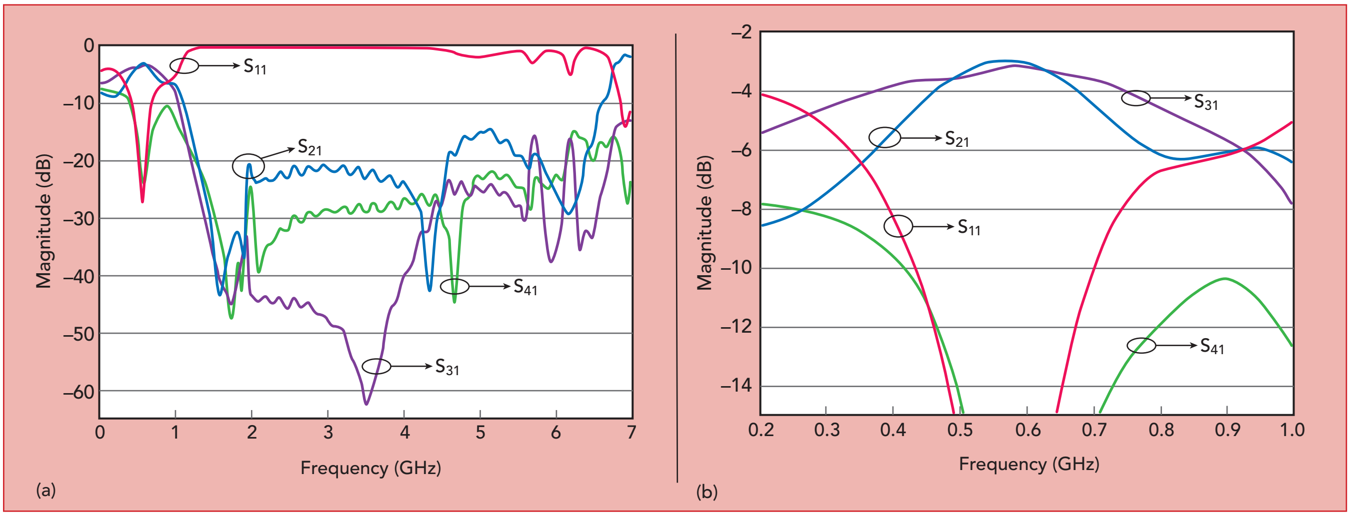

Fig. 4 Measured $|S_{xx}|$ from DC to 7.0 GHz (a) and 0.2 to 1.0 GHz (b).

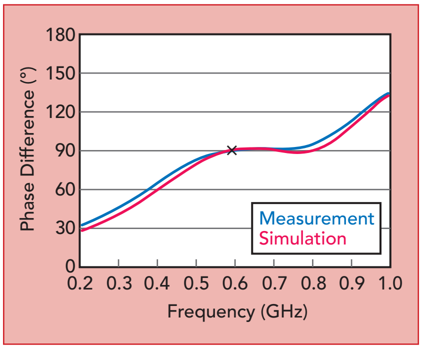

Fig. 5 Phase difference between S_{21} and S_{31}.

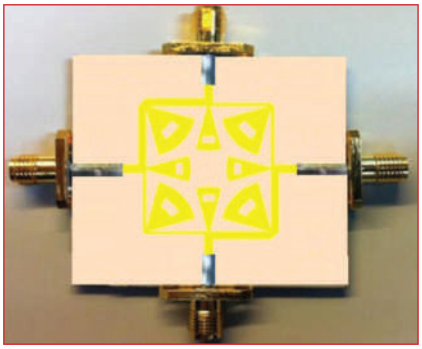

Fig. 6 Prototype coupler.

mm^2. By comparison, this prototype represents a surface area of 14.8 percent (see ***Figure 6***). ***Table 1*** compares the performance of the prototype coupler with previous work.

CONCLUSION

A new microstrip branch-line coupler uses modified radial stub loaded resonators to achieve compact size and wideband harmonic suppression. With eight modified radial stubs placed inside its free area, the occupied area is reduced to 14.8 percent of a conventional design at 580 MHz. The in-band performance is comparable to that of a conventional design and suppresses up to the eleventh harmonic. The measured performance agrees closely with the design simulation. ■

ACKNOWLEDGMENTS

This work was supported by the Natural Science Foundation of China under Grant Nos. 61377080 and 61302842.

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TABLE 1
COUPLER PERFORMANCE COMPARISON

Reference	Relative Area (%)	Harmonic Suppression
Conventional	100	No
5	63	NA
6	58	5th
7	24	3rd
8	28	2nd
9	29.3	4th
10	26.8	2nd
11	25	4th
12	90.4	2nd
13	60	NA
14	74	NA
16	56.8	2nd
This Work	14.8	11th

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The frequency ranges used by RF applications like 5G new radio (5G NR) and automotive radar require engineers to use a spectrum analyzer for insights when developing new systems. The latest digital oscilloscopes from Rohde & Schwarz, the R&S RTO6 series, contain low noise analog front-ends and high sampling rate analog-to-digital converters (ADCs) with excellent spurious-free dynamic range. Their signal integrity capabilities strengthen the inherent utility of oscilloscopes, including digital triggering and multiple inputs for phase-coherent measurements.

Launched in July, the R&S RTO6 is the next generation of 6 GHz oscilloscopes from Rohde & Schwarz. To enhance usability, it has a new user interface, including a 15.6 in. HD touchscreen with a redesigned front panel. The enlarged display maximizes the waveform viewing area and the R&S SmartGrid lets users drag and drop signals to various locations on the screen. The "app cockpit" provides access to all the oscilloscope's applications with a single tap.

With 6 GHz input bandwidth and a sampling rate of 20 GS/s, the R&S RTO6 will sample high frequency signals without analog down-conversion, and the acquisition rate of 1 million waveforms per second enables detecting sporadic signal anomalies. The instrument's digital triggering operates on the ADC samples and can be enhanced to 16-bit vertical resolution in the high definition mode. Direct triggering on high-resolution signals captures signal details, which is not possible with conventional analog triggers that split the measurement signal into two paths. The result is lower trigger jitter, en-


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Fig. 1 The R&S RTO6 displays the time and frequency responses of multiple channels simultaneously.

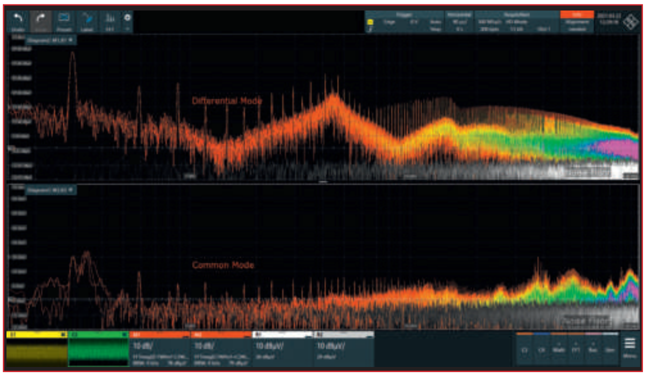

Fig. 2 The FFT spectrum analysis function is useful for measuring EMI, such as conducted disturbance.

abling the trigger sensitivity to be optimized for a given application. These attributes enable accurate detection of short, intermittent, burst and pulsed signals, as well as low signal levels, making the instrument valuable for automotive radar applications.

MULTI-ANTENNA WIRELESS DEVELOPMENT

With phase-coherent multi-channel acquisition, the R&S RTO6 is a powerful tool for developing multi-antenna designs. Radar systems use this to estimate the angle of arrival of an object, using the phase differences among multiple receive paths to detect the direction of approaching objects.

Furthermore, 5G NR uses multi-antenna technology for beamforming, i.e., to transmit a signal in a desired direction. A defined phase shift is generated for each adjacent input signal stream, maintaining a constant phase shift is important to keep the beam stable and pointing in the desired direction. The R&S RTO6 provides a phase-coherent measurement of four input streams, which can handle up to four signals within a single 5G NR channel. It also performs MIMO measurements, such as the phase difference between input signals to characterize beams during transmitter testing.

When working with automotive radar applications in the 77 to 81 GHz range, as well as 60 GHz radar for gesture sensing, the signal exceeds the oscilloscope's bandwidth. This limitation can be overcome using an external mixer, such as the R&S FS-Zxx series, to downconvert the signal. And to compensate for losses from additional components in the signal path, Rohde & Schwarz oscilloscopes have real-time de-embedding capabilities. For all use cases mentioned above, engineers can use the oscilloscope's built-in measurement tools for basic analysis or the more comprehensive pulse and transient analysis options available in the R&S VSE software suite.

MULTI-DOMAIN ANALYSIS

Compared to spectrum and frequency analyzers, another strength of oscilloscopes is the capability to analyze both time and frequency domains, measure power, monitor trigger signals and decode buses. This range of capabilities enables correlating RF signals with the supply voltage or digital bus, using the time alignment maintained among all the measurements (see ***Figure 1***). This helps when analyzing interactions among subsystems that need to work together. The R&S RTO6 can acquire radar signals simultaneously with CAN bus or automotive Ethernet signals, measuring the delay between the radar and bus protocol signals to determine characteristics like the radar's analysis time.

When the correlation of frequency and time is important, designers can use the fast Fourier transform (FFT) capabilities of the R&S RTO6. One example is the UWB 802.15.4z standard, which is used for applications such as automotive keyless entry. The R&S RTO6 can inspect the UWB signal in both time and frequency simultaneously, adjusting measurement settings as needed. It also has the same gated FFT feature of other Rohde & Schwarz oscilloscopes, which lets users select a portion of a signal in the time domain and plot the spectrum of that segment. Spectral measurements like channel power and occupied bandwidth can be set to focus on the spectral properties of a specific pulse or when debugging a device being tested.

SOLVE EMI

This same approach can be applied when debugging the electromagnetic interference (EMI) performance by using dedicated near-field probes—provided with Rohde & Schwarz oscilloscopes—with the FFT and trigger capabilities (see ***Figure 2***). The R&S RTO6 can locate EMI signals and sources of spurious emissions on a board, which helps identify and deal with problems earlier in product development, saving the time and expense of fixing issues later in the project.

In addition to spectrum analysis using FFT, the oscilloscope provides applications including automated compliance testing of high speed interfaces, decoding serial protocols and measuring power electronics, with available software options to support special applications. All measurement functions are preinstalled on the oscilloscope and can be enabled with a keycode after the unit is purchased.

VENDORVIEW

Rohde & Schwarz
Munich, Germany
www.rohde-schwarz.com

90 GHz Multicoax Interconnect for High Speed Digital Testing

HUBER+SUHNER AG
Herisau, Switzerland

Semiconductor ICs are the key components of complex electronic circuits. In countless technical applications, these small processing, control and memory components help master the great challenges of our time. Global trends such as the digital transformation of society and the economy require highly integrated ICs able to process ever higher data rates. To support this pace of development in the semiconductor industry, measurement systems must also extend their capabilities to ever higher frequencies.

The semiconductor, automotive and mobile communications sectors act as technology drivers for interconnects, as they are creating applications that use frequencies well into E-Band. Familiar examples of applications between 60 and 90 GHz include advanced driver assistance systems using radar for active cruise control, the PAM4 high speed data standard for 400G Ethernet and 5G and 6G infrastructure for mobile communications.

Responding to these trends, HUBER+SUHNER has developed a precision multicoax test solution for the high speed digital testing (HSDT) market. The MXPM90 reliably measures signals from DC to 90 GHz, while taking up only a small footprint on the board. The MXPM90's broadband coverage and high signal integrity are each a prerequisite for the strength of the multicoax connector system, which provides an almost ideal interconnect from DC through 90 GHz.

HIGH FREQUENCY, HIGH DATA RATES

When a new generation of ICs with data rates of 112 Gbps completes design simulation, it is fabricated on a wafer, with wafer probing used for the first electrical tests. The wafer is then cut and the individual ICs are packaged and mounted on a printed circuit board (PCB) for evaluation. Benchtop testing of the prototype requires a setup and test system that guarantees accurate and repeatable measurements. The interconnect from the test system to the IC must be transparent, i.e., with low insertion loss, low VSWR and tight phase matching among channels and consistent performance across the full operating bandwidth of the system. The measurements must be repeatable when the connectors are plugged and unplugged over the lifetime of the setup. The size of the interconnect is also important, i.e., how close the measurement system can be to the IC to minimize line losses on the PCB. These are the key considerations when designing a test setup and its interconnects.

Addressing these requirements, the MXPM90 from HUBER+SUHNER consists of a PCB socket, optimized for low interference signal transmission, and the single interconnect cable assemblies, which are electrically and mechanically stable but still exhibit excellent flexibility. The combination provides a 90 GHz connection from the PCB to the measurement system or to another PCB connector. HUBER+SUHNER produces both the connector and proprietary cable internally, optimizing them to be compatible.

The MXPM90 breakout assemblies have 1 mm connectors, which are designed for 110 GHz, with the complete assembly specified to 90 GHz. The predecessor MXPM70 uses 1.85 mm connectors, which have an

upper frequency of 70 GHz. Normally, the tracks on the PCB have high insertion loss at mmWave frequencies, so the design goal is minimizing the track length and moving into a coaxial structure as soon as possible, meaning the connectors should be located close to the IC. Designed to minimize this distance, the MXPM90 has a short 2.54 mm center-to-center spacing between adjacent channels.

SIGNAL INTEGRITY

The MXPM90 offers excellent signal integrity to 90 GHz, minimizing noise, reflections, distortion and losses. ***Figure 1*** shows the time domain reflectometry (TDR) response of a typical impedance transition from a PCB to an MXPM cable assembly. The PCB signal trace (designated as 2 in the figure) is a coplanar line with w = 0.28 mm and gap = 0.2 mm fabricated on a 5 mil thick Rogers 3003 substrate with $\varepsilon_r = 3$.

The signal trace on the evaluation board shown in the figure has an impedance of approximately 48 Ω, with a tolerance of ±5 Ω due to manufacturing variation. It ends in a landing pad where the inner conductor pin of the MXPM presses. The low impedance—therefore capacitive behavior—of the pad is compensated for with a constriction in the signal track. The deflections in the TDR diagram show the electrical discontinuities of the MXPM cable assembly. The highest value, which also poses the highest uncertainty, is at the transition to the Multiflex-53 cable, which has an impedance of about 49.5 Ω, with a tolerance of ±2 Ω from the manufacturing process. Optimized for high frequency performance, the maximum ripple is 2.5 Ω.

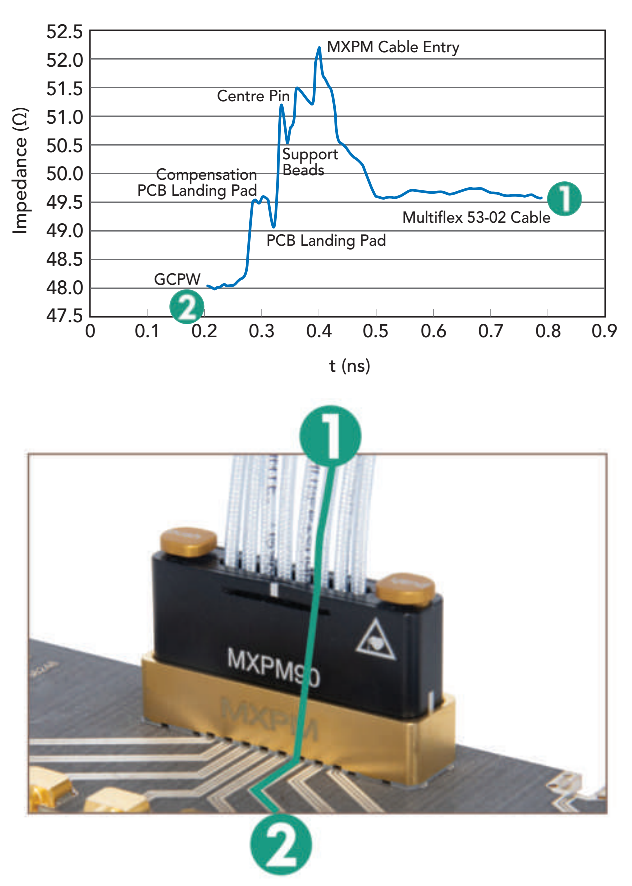

Fig. 1 **TDR measurement of a typical transition from a PCB to MXPM system.**

Phase matching among the channels of a single interconnect assembly have an electrical length tolerance of only ±1 ps. Keeping this low was an integral part of the MXPM90 design.

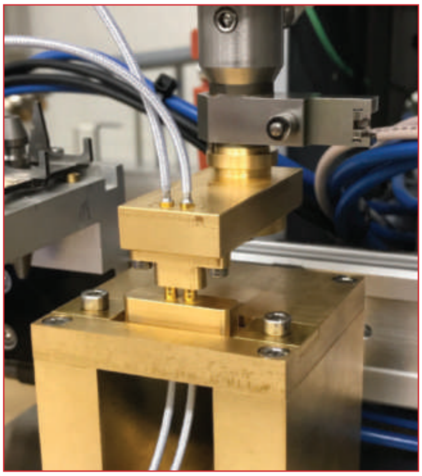

Fig. 2 **Plug cycle test setup.**

REPRODUCIBLE

A plug cycle test demonstrates the reproducibility and durability of the MXPM series. In the test, a single channel of the MXPM CAY is connected to a special coaxial adapter, which presses the two cable connectors together until they reach a defined reference surface and make the electrical connection (see ***Figure 2***). During this process, the outer conductor crown of the MXPM male single channel slides into the insertion cone of the MXPM female single channel and the spring pin of the MXPM male connector presses onto the flat inner conductor of its counterpart.

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1801	30	0.49 / 1.62
1701	38	0.57 / 1.88
1571	40	0.64 / 2.09
1501	40	0.75 / 2.46
1401	50	1.02 / 3.34
1251	70	2.14 / 7.02
0471	110	4.95 / 16.23

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To document the durability of this MXPM coupling, several MXPM single channels were connected 50,000 times, with the S-parameters measured after every 50 couplings, yielding 1,000 total S-parameter measurements during the 50,000 cycles. *Figure 3* shows the wear on the connector interfaces after 50,000 cycles. Across the 1,000 data sets, the insertion loss change was less than ±0.1 dB (see *Figure 4a*), although it increases at the upper frequencies as the number of cycles increases. Combining the data from the 1,000 measurements, *Figure 4b* shows the mean and ±6 sigma values of insertion loss versus frequency for a 0.66 m length.

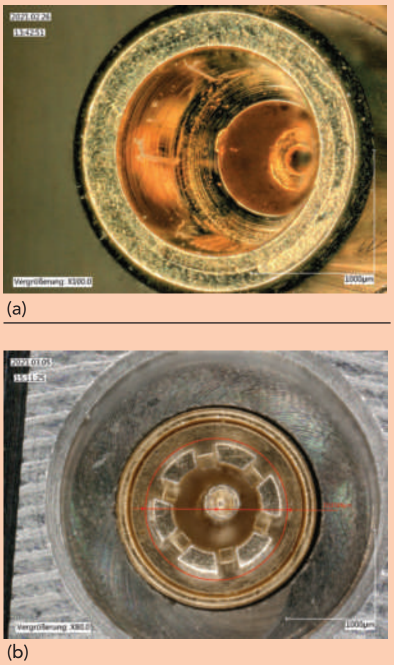

Fig. 3 **Wear after 50,000 plug cycles: female (a) and male (b) interfaces.**

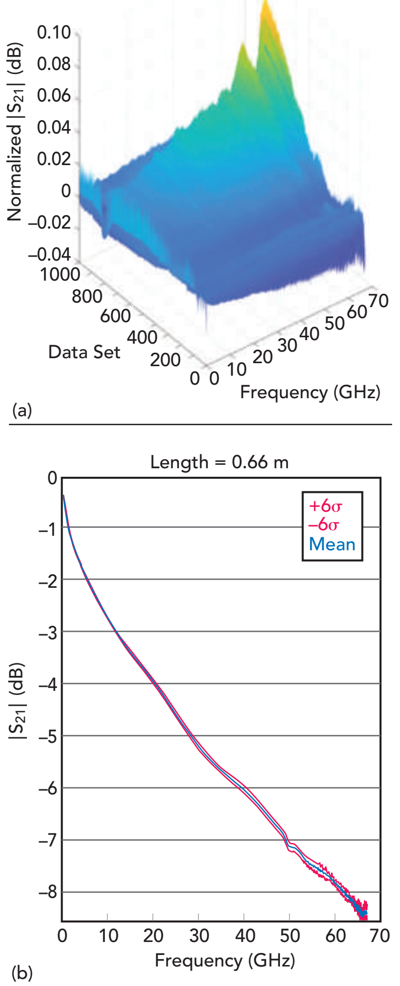

Fig. 4 **20 MHz to 67 GHz insertion loss vs. measurement count, normalized to the first measurement (a). Mean and ±6 σ values of the insertion loss vs. frequency, combining all 1,000 measurements (b).**

PROVEN HERITAGE

The 90 GHz coverage of the MXPM90 is the latest extension of HUBER+SUHNER's proven MXPM multicoax line, which has been used in various markets for over a decade. The higher frequency connector system supports highly accurate and reliable measurements of both digital and mmWave signals, and the coaxial design of the latest version of MXPM both extends frequency coverage and enhances shielding and signal integrity. As the direct successor to the MXPM70, the MXPM90 retains the features that have made the MXPM series well respected in the industry: electrical performance, easy handling and high quality. For example, the MXPM has a magnetic locking mechanism enabling "plug and play"—a consistent transition between the module and the PCB socket every time it is plugged in, which is unique in the HSDT market. Another feature is automatic interface protection to protect the contacts from mechanical damage as soon as the connector is disconnected.

SUMMARY

The semiconductor, automotive and mobile phone sectors are driving IC development. To meet the demands of the industry for testing ever higher data rates and frequencies, HUBER+SUHNER has developed the MXPM90. Based on a new multicoax connector system, the Swiss-based technology company can offer all industries a nearly "future-proof" test solution.

HUBER+SUHNER AG
Herisau, Switzerland
www.hubersuhner.com

Tight Bending mmWave Cable Assemblies for Space-Constrained Systems

Times Microwave Systems
Wallingford, Conn.

Times Microwave Systems has designed a family of microwave cable assemblies for the small electronics boxes being used in emerging RF applications. InstaBend™ cables are extremely flexible for bending around tight corners, using a new connector design that reduces the required space behind the connector. This helps fit more cables within a small space while maintaining low loss and VSWR.

InstaBend assemblies are offered in two sizes: InstaBend 086 and InstaBend 047 (see ***Table 1***) and are available in various lengths to make connection with minimum footprint. Connector types including SMP, SMA and 2.92 mm. InstaBend is available within short lead times: standard configurations are stocked by many distributors, including DigiKey and Mouser, and custom configurations are available from Times Microwave with lead times of two to four weeks.

TABLE 1
INSTABEND CABLE FAMILY

	InstaBend 047	InstaBend 086
Diameter	0.061 in. (1.55 mm)	0.10 in. (2.67 mm)
Minimum Bend Radius	0.13 in. (3.30 mm)	0.25 in. (6.4 mm)
Operating Temperature	–65°C to +125°C	–65°C to +125°C
Maximum Frequency	110 GHz	62 GHz
Weight	0.005 lb/ft	0.01 lb/ft

THE RIGHT FIT

The ever higher frequencies of RF/microwave communications require installations densely packed with even more technology in tight spaces. The tighter packaging makes cabling from the front panel to the board more complicated, as packing more interconnects into smaller spaces is tricky.

Semi-rigid cables have traditionally been used for these applications, but they are fragile and prone to break with tight bends, making them challenging to use in small spaces. Semi-rigid is also more complicated and time consuming to manufacture because the cables must be bent to their final configurations at the factory. The new InstaBend line can reduce system design work when compared to semi-rigid assemblies that require predetermined bends, saving substantial engineering time and money.

5G RF Components & Cable Assemblies

Whether you're building the future of enhanced mobile broadband or designing applications for IoT and mission-critical communications, Fairview Microwave offers the most extensive portfolio of in-stock and ready-to-ship 5G RF components and cable assemblies. Fairview Microwave is ready to support 5G innovation, testing, and deployments, through an expansive product offering, product support, and a commitment to same-day shipping.

Fairview Microwave offers thousands of active, passive, interconnect, and antenna products for global sub-6 GHz and mmWave frequency bands as well as technical service and application engineers are standing by to answer.

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InstaBend, on the other hand, offers more flexibility. It is designed to interconnect between RF circuit cards, modules and enclosure panels in the tightest spaces while maintaining excellent RF/microwave performance. The cable bends close to the connector to minimize cable routing and save space. The assemblies are rugged, using the solderless attachment of the cable outer conductor to the connector. This crimp-on assembly is reliable and eliminates a solder joint that can break under stress, such as when the cable assembly is bent.

APPLICATIONS

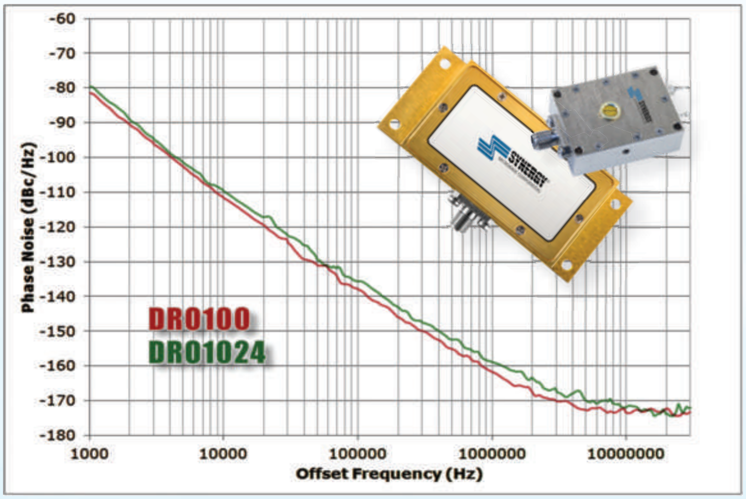
InstaBend's flexibility makes it well suited for aircraft, test and measurement—any commercial or military application where space is constrained. Times Microwave first developed these RF board solutions to meet stringent military specifications for flight applications, where performance is more important than cost. However, commercial applications such as 5G demand more economical and scalable solutions, so Times used its experience with military products to develop InstaBend at a price suitable for commercial markets, where price is one of the primary requirements.

InstaBend cable assemblies provide highly reliable interconnections to meet the growing demand for miniaturization in small electronic equipment. These cable assemblies meet the electrical, mechanical and environmental requirements of emerging applications such as 5G and automotive radar, providing performance to mmWave frequencies with ruggedness for many applications. To keep development schedules on time, InstaBend cable assemblies are available in standard configurations through distribution and custom assemblies can be delivered in a few weeks.

Times Microwave Systems
Wallingford, Conn.
www.timesmicrowave.com
techquestions@timesmicro.com

Exceptional Phase Noise

Dielectric Resonator Oscillator



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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	1 - 10	+8 @ 25 mA	-110
SDRO800-8XT [1]	8	1 - 10	+8 @ 25 mA	-110
SDRO900-8	9	1 - 10	+8 @ 25 mA	-112
SDRO900-8XT [1]	9	1 - 10	+8 @ 25 mA	-112
SDRO1000-8	10	1 - 15	+8 @ 25 mA	-107
SDRO1024-8	10.24	1 - 15	+8 @ 25 mA	-105
SDRO1118-7	11.18	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	11.34	1 - 12	+5.5 - 7.5 @ 25 mA	-107
SDRO1140-8XT [1]	11.4	1 - 10	+8 @ 25 mA	-102
SDRO1250-8	12.5	1 - 15	+8 @ 25 mA	-104
SDRO1300-8	13	1 - 12	+8 @ 25 mA	-104
SDRO1400-8	14	1 - 12	+8 @ 25 mA	-102
SDRO1500-8	15	1 - 12	+8 @ 25 mA	-100
Connectorized Models				
DRO80	8	1 - 15	+7 - 10 @ 70 mA	-114
DRO8R95	8.95	1 - 10	+7 - 10 @ 38 mA	-109
DRO100	10	1 - 15	+7 - 10 @ 70 mA	-111
DRO1024	10.24	1 - 15	+7 - 10 @ 70 mA	-109
DRO1024H	10.24	1 - 15	+7 - 10 @ 70 mA	-115
KDRO145-15-411M	14.5	*	+7.5 @ 60 mA	-100

New Models! (SDRO1300-8, SDRO1400-8, SDRO1500-8)

* Mechanical tuning only ±4 MHz
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Portable 20 Watts Power Amplifier Covers 700 MHz to 2.7 GHz Cellular Bands

thinkRF has developed a portable, rugged, discrete and cost-effective multiband cellular power amplifier (PA) for public safety and emergency communications. Covering the mobile wireless bands between 700 MHz and 2.7 GHz, the H1000A provides 20 Watts maximum power output with adjustable gain to 43 dB. The PA has a dual-band architecture (i.e., high and low bands) for optimizing PA-antenna performance, with two TNC output ports for the two bands. The PA is designed to be used with more signal sources and operational scenarios than other PAs with similar electrical performance.

thinkRF describes the H1000A as the first "intelligent" multiband cellular PA, containing a microcontroller to simplify setup by verifying it is meeting all performance requirements prior to deployment. After the unit is fielded, the microcontroller monitors the health of the PA and diagnoses any problems. The PA is light enough to be carried in a backpack, or it can be mounted in a vehicle. It can also be networked and left unattended for remote applications.

The thinkRF H1000A PA was designed to ensure rain and dust will not interfere with operation and has an IP66 rating for the enclosure and connectors. The unit has no fan, so operation is silent and reliable. Built-in power filtering, surge suppression and regulation protect the PA from external power transients. It can be powered by two off-the-shelf V-mount batteries, available at many camera stores, and a "hot swappable" feature enables the batteries to be changed while the PA is operating. Seamless switching between the battery and 12 V external power keeps the unit running uninterrupted.

The H1000A PA was designed and is manufactured in Canada.

thinkRF
Ottawa, Canada
www.thinkrf.com

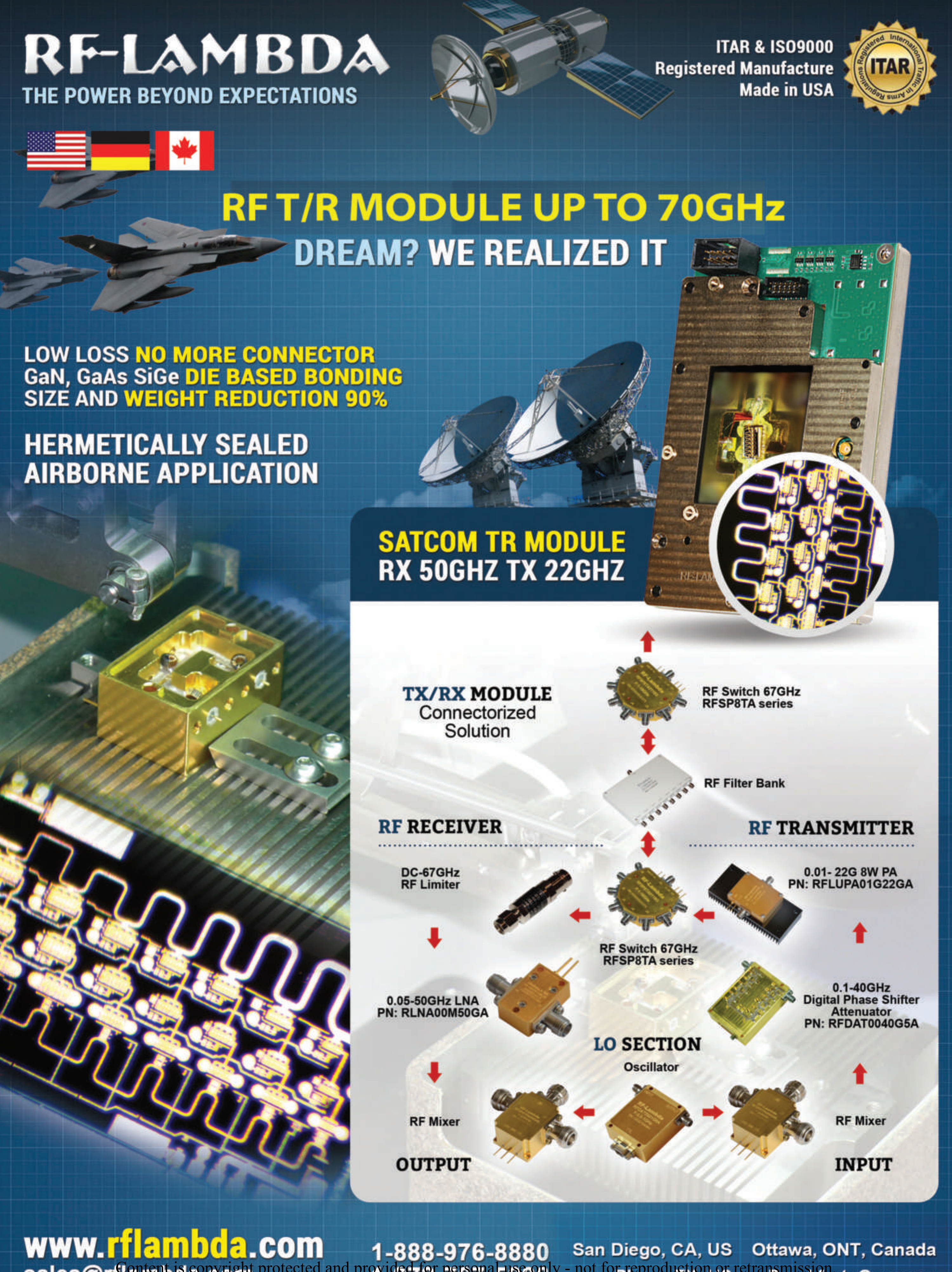
Ultra-Low Loss Multi-Layer PCBs

Panasonic Corporation recently launched the R-5410 printed circuit board (PCB) prepreg, a halogen free material for multi-layer circuit boards with ultra-low transmission loss. The R-5410 material is well suited for automotive radar, 5G base stations and other mmWave systems. The material is compatible with multi-layer antenna construction using standard PCB lamination processes and equipment, which improves antenna efficiency, reduces material and manufacturing costs and provides design flexibility.

mmWave frequencies are enabling a new generation of automotive, terrestrial wireless, satellite and other applications. mmWave radar is a core sensor for the advanced driver assistance systems being deployed on new vehicles. Multi-element antenna beamforming architectures have been adopted for 5G base stations operating at the FR2 mmWave bands. The rapid adoption and wide deployment of these mmWave systems has increased the market demand as well as the performance requirements for the PCBs at the heart of these radios.

Historically, fluoropolymer-based materials were used for manufacturing antenna boards. However, fluoropolymers are intrinsically thermoplastic and can be difficult to process for multi-layer PCB construction. Panasonic's R-5410 multilayer circuit board material prepreg is manufactured using a unique non-fluoropolymer thermosetting resin system, which is halogen free and has ultra-low transmission loss. This new system has stable dielectric properties, good adhesion strength—even using low profile copper foils—and has 0.079 dB/mm loss at 79 GHz, the lowest in the industry for thermosetting resin circuit boards. The R-5410 material system supports multi-layer antenna construction using standard manufacturing processes and equipment for circuit board lamination, enabling the development of compact, high density modules with integrated antennas for lower material and processing costs.

Panasonic Corporation
Osaka, Japan
www.panasonic.com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Testing 4D Imaging Radar Sensors

Ultra-high-resolution imaging radars provide detailed images of the radar's surroundings. Learn how to test and validate these sensors with dSPACE's new DARTS 9040-G radar target simulator with true 5 GHz bandwidth.

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Exodus 80 MHz to 6 GHz Quick Walkthrough

Enjoy this brief Exodus video highlighting some of the company's 80 MHz to 6 GHz amplifiers. Visit the website to see their entire product range 10 kHz to 50 GHz.

Exodus Advanced Communications
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New Blog Post: Supply Chain Security & Infrastructure ICS/OT

Keysight Technologies' Senior Industrial Solutions Manager, Gal Ow, covers what is supply chain security and what it means to Critical Infrastructure ICS/OT in a new blog post.

Keysight Technologies Inc.
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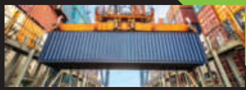

Overcoming Technology Barriers

Passive components such as power dividers, combiners, couplers and hybrids are indispensable parts of wireless systems. MIcable is overcoming the technology barriers with higher frequency, wider bandwidth, higher power, better performance and smaller size.

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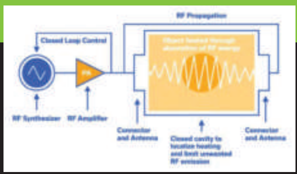
Turnkey Solid-State Amplifiers for ISM RF & Microwave Energy

The realization of RF and microwave energy through solid-state technologies has enabled unprecedented control over frequency and power for more sensitive applications, read more in this blog post.

Mini-Circuits
https://blog.minicircuits.com/turnkey-solid-state-amplifiers-for-ism-rf-microwave-energy/



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BRAND NAME VNA EXTENSION | RUGGED CASE | ADJUSTABLE POWER

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There are total six models to extend the 20 GHz VNA to cover 50 to 220 GHz operation. The vector network analyzer (VNA) frequency extenders designed to achieve full 2-port, S-parameter testing. They are compatible with modern vector network analyzers such as the Copper Mountain CobaltFx C4220, Rohde & Schwarz ZVA Series and Keysight PNA-X Series. In addition, a RF output power control attenuator with control range of 0 to 20 dB is integrated to reduce the port output power to prevent the saturation of the amplifier testing.

Optional Cal Kits

The matched cal kits are available as VNA extenders companies. These cal kits are offered under the series of STQ family. They are offered under nine models and can be NIST tracible.

Adjustable Power

These VNA extenders offer an adjustable outpower power from 0 to 20 dB with the turn of a knob.

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PMI Technical Capabilities & Facilities Presentation

This interactive presentation outlines PMI's technical and design capabilities as well as their facilities located in Maryland and California. Includes links to PMIs services, online catalog and videos.

Planar Monolithics Industries, Inc.

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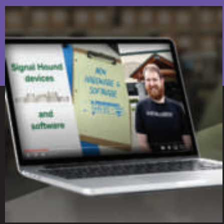
New Products for 2021 and a Message from Signal Hound's VP

Learn about Signal Hound's proven products: SM200C/B, BB60C, SA series, VSGs and Spike in this new video. Check out the SM435B and BB60D coming October 2021 and Q1 of 2022.

SIGNAL HOUND

www.youtube.com/watch?v=iMwn7CpFHug



Pre-Tinned (De-golded) PCB Connectors

SV Microwave's Pre-Tinned (de-golded) PCB Connectors avoid gold embrittlement to create a stronger bond between the PCB connector and board surface. Learn more about these connectors in SV's new video.

SV Microwave

https://bit.ly/3eYXc3v

InstaBend

In this episode of Reel Times, Director of Commercial Sales Dave Kiesling discusses the new InstaBend assemblies and their many applications.

Times Microwave

www.youtube.com/watch?v=acHv2kzI9zk

NEW PRODUCTS

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COMPONENTS

Filters

3H printed filters are field proven for military, space and commercial applications. Frequency range: 5 GHz to 47 GHz, type: BPF, LPF, HPF, BRF and multiplexer options, bandwidths: 1 to 60 percent and Chebyshev response. Low profile packages start at < 0.065. Available with connectors and SMT, Mil-Std-202 conditions.

3H Communication System
www.3hcommunicationsystems.com

Power Dividers/Combiners

MIcable developed a series 0.45 to 6 GHz 2-, 4-, 6-, 8- and 16-way power dividers, they can handle higher forward and reverse power, have lower insertion loss, 16 dB minimum isolation, ±0.5 dB amplitude and ±5 degrees phase unbalance. More importantly, all units are manufactured with good performance consistency and most of cases stocks are for sales.

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

Bandpass Filter
VENDORVIEW

Mini-Circuits' model BFCV-2852+ is a low temperature co-fired ceramic bandpass filter with low loss passband of 28.0 to 28.8 GHz. Measuring just 3.2 × 2.5 mm but capable of handling input power levels as high as 1 W (+30 dBm), the 50 Ω filter is ideal for miniaturized, densely packed, highly circuits such as for 5G wireless equipment. The cost-effective ceramic filter exhibits typical passband insertion loss of 2.3 dB from 28.0 to 28.8 GHz with typical return loss of 11 dB.

Mini-Circuits
www.minicircuits.com

Absorptive Switch
VENDORVIEW

PMI Model No. P4T-500M40G-60-T-55-292FF-SP Rev. B is a 500 MHz to 40 GHz, ultra-compact, high speed, single pole, four throw, absorptive switch. This switch offers over 60 dB of port-to-port isolation while maintaining an insertion loss of 8 dB maximum. The switching speed is less than 50 ns and is controlled by 2-bit decoded TTL. Maximum operating power is +20 dBm CW and the VSWR is 2.5:1 maximum. The compact housing measured only 2.0" × 1.0" × 0.4" and is supplied with 2.92 mm female connectors.

Planar Monolithics Industries
www.pmi-rf.com

Mixed-signal RF Converters

Richardson RFPD Inc. announced availability and design support of two highly integrated high speed converters from Analog Devices, Inc. The AD9081 and AD9082 mixed-signal front-ends combine high performance analog and digital signal processing and allow designers to install multiband radios in the same footprint as single-band radios. By shifting more of the frequency translation and filtering from the analog to the digital domain, the AD9081/2 provides designers with the software configurability to customize radios.

Richardson RFPD Inc.
www.richardsonrfpd.com

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 connectors (waveguide 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

CABLES & CONNECTORS

Ultra-Flexible Cable Series
VENDORVIEW

Introducing Littlebend™ ultra-flexible cable series by HASCO, Inc. These extremely flexible, triple shielded cables support a minimum bend radius of 0.20" and a high retention force of > 90 N eliminating the need for right-angle adapters. The Littlebend HLB098 cables are designed for demanding microwave interconnect applications and system designs requiring dense packaging. HASCO's new Littlebend™ ultra-flexible cable series are 100 percent tested for VSWR and insertion loss and available in a variety of standard lengths.

Hasco
www.hasco-inc.com

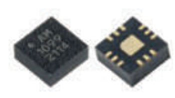
SMPM Cable Assemblies

Samtec now offers mmWave cable assemblies with SMPM jack and plug connectors on 23 AWG low loss flexible cable (RF23C Series). RF23C Series offers a frequency range of DC to 50 GHz and a maximum VSWR of 1.40. Cable construction includes three layers of shielding: SPC flat wire, copper foil and a 44 AWG outer braid. SMPM is a miniature push-on connector.

Samtec
www.samtec.com

AMPLIFIERS

Cascadable Amplifier
VENDORVIEW



AM1099 is a microwave cascadable amplifier providing moderate gain and low noise figure making it a useful component for applications such as 5G wireless and Ka-Band satcom. It offers high frequency servicing the 26 to 32 GHz frequency range. The device exhibits moderate gain and noise figure which makes the AM1099 a useful component for applications such as 5G wireless and Ka-Band satcom. Packaged in a 3 mm QFN with internal 50 Ω matching, the AM1099 represents a compact total PCB footprint.

Atlanta Micro Inc.
www.atlantamicro.com

Solid-State Power Amplifier
VENDORVIEW

Exodus AMP2070D-LC, ideal for broadband EMI-Lab, communication and electronic warfare applications. Class A/AB linear design for all modulations and industry standards. Covers 1 to 6 GHz, producing 200 W minimum, 150 W P1dB and 53 dB minimum gain. Excellent

IMS

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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 Systems 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

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

19-24 June 2022

MICROWAVE WEEK IMS2022, RFIC 2022, ARFTG, and Exhibition

New**Products**

flatness, optional monitoring parameters for forward/reflected power, VSWR, voltage, current and temperature sensing for superb reliability and ruggedness. Integrated in its compact 5U chassis weighing approximately 40 kg.
Exodus Advanced Communications
www.exoduscomm.com

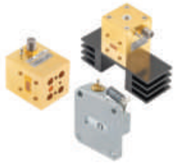
Traveling Wave Tube Amplifiers

Quarterwave announced its new traveling wave tube amplifiers—the Compact Commercial Series. These units specialize in low noise, high PRF and are available for rugged applications. Upgraded with a modern exterior chassis, the Compact Commercial Series features better durability, improved control system and optional touch-screen interface. Amplifiers are high-powered for pulsed CW operations, mid-range from 8 to 18 GHz, with high PRF options from 1 to 3 MHz. Units are fully customizable to meet customer project needs.
Quarterwave
www.quarterwave.com

SOURCES

Waveguide Gunn Diode Oscillators

VENDORVIEW



Pasternack has released a new line of waveguide Gunn diode oscillators that are ideal for EW, electronic countermeasures, microwave radio systems, military and commercial communications systems and more. The new mechanically tunable waveguide Gunn diode oscillators cover WR-90, WR-42 and WR-28 waveguide sizes and support X-, K- and Ka-Bands. All models in this line operate at 50 ohms and incorporate a mechanical tuning screw to fine tune the output frequency for specific applications.
Pasternack
www.pasternack.com

MEMS-based TCXO Alternative

VENDORVIEW

RFMW announced design and sales support for SiTime's ultra-small, µPower, 32.768 kHz TCXO. SiTime's TempFlat MEMS technology enables the first 32 kHz TCXO in a 1.2 mm² chip-scale package. Typical core supply current is only 4.5 µA. The SiT1566 is factory calibrated over multiple temperature points to guarantee extremely tight, ±3 ppm all-inclusive frequency stability.
RFMW
www.rfmw.com

SOFTWARE

Spectrum Analysis Software

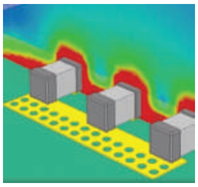
VENDORVIEW

This IP65 and MIL-STD-810G certified outdoor spectrum analyzer is predestined for real-time spectrum monitoring and interference hunting on the way. It offers all the benefits of an extremely rugged laptop combined with its SPECTRAN® V6 real-time spectrum analyzer with up to 245 MHz RTBW (I/Q) between 10 MHz to 6 GHz. The pre-installed RTSA-Suite PRO software allows signals to be displayed and analyzed in real time in a wide variety of ways.
Aaronia AG
www.aaronia.de

Modelithics COMPLETE+3D Library

VENDORVIEW

Modelithics announced the release of new models for a wide range of quad-flat no-leads packages from Barry Industries. The new models include both 3D and equivalent-

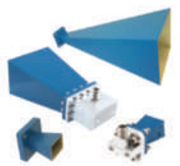


circuit models for 18 different packages that range in size from 3 to 8 mm, for a total of 36 new models. Among the 18 packages are three different 3 mm versions and six different 4 mm versions. In addition, three different 6, 7 and 8 mm versions are included.
Modelithics
www.modelithics.com

ANTENNAS

Waveguide Horn Antennas

VENDORVIEW



Fairview Microwave Inc. has released a new series of standard gain, waveguide horn antennas that can be used in a wide range of test and measurement, wireless communication, government/military, R&D and microwave radio systems applications. The new waveguide horn antennas are made in the U.S. and are TAA-compliant. With low loss, high-power handling capability, high directivity and near constant electrical performance, they are ideal for a range of applications.
Fairview Microwave Inc.
www.fairviewmicrowave.com

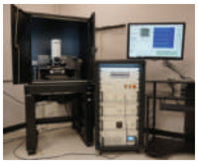
TEST & MEASUREMENT

The Proxi-Flange™

VENDORVIEW

The Proxi-Flange™ is constructed with a special waveguide flange populated with an array of small pin-like structures to realize RF choking actions. The Proxi-Flange™ avoids the problem of poor return loss and high insertion loss caused by imperfect contact when two waveguide flanges are mated. The captive screws normally used in waveguide test sets can cause cocking issues if tightened unevenly, but the Proxi-Flange™ eliminates the need for any waveguide screws.
Eravant
www.eravant.com

Advanced Thermal Imaging System



Microsanj offers a customer-configurable modular platform that can be customized to address application-specific thermal requirements. Whether trying to address thermal imaging challenges of 5G, automotive, military, smart-city or other mission-critical applications, the ability to configure a system with application-specific features and functionality ensures that customers can easily gain an understanding of device and component static and time-dependent thermal behavior.
Microsanj
www.microsanj.com

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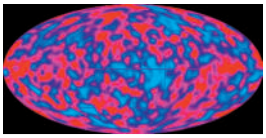
IEEE Journal of Microwaves

"Expanding science, technology and connectivity across the globe."

We have just released our October issue of ***IEEE Journal of Microwaves***, completing our first year of this new high-quality, broad-interest, fully-open-access research journal reaching out to the *whole* of the microwave community. **You can read or download any and all of our articles for free at: https://ieeexplore.ieee.org**

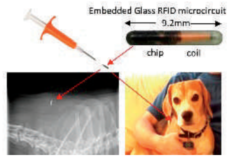
Within our first volume (2021), we have already published more than 80 manuscripts covering popular microwave research topics from 5G/6G communications and automotive radar, to power beaming and quantum computing. These papers have generated ***more than 80,000 views*** - which have resulted in our new journal being ranked 14^{th} of 375+ established IEEE publications in usage (downloads) for published articles in the January-June 2021 time period (the most recent period for which these statistics are available)!

In addition to high-quality research, we carry special general interest topical and tutorial papers in every issue under our continuing series: ***Microwaves are Everywhere.*** These now include: *Cosmic Microwave Background: Hiding in Plain Sight*; *Ovens: From Magnetrons to Metamaterials*; *RFID: Do You Know Where Your Pet Is?* and *Scanning Microwave Microscopy: nano-Microwaves*. Three other very popular series alternate issues: (1) ***Microwave Pioneers*** (biographical articles composed from live interviews) which now include Carver Mead (first microwave GaAs transistor), Nobel Laureate John Mather (Cosmic Microwave Background), Arye Rosen (microwaves in medicine), and Kam Lau (microwaves over fiber); (2) ***Breakthroughs in Microwaves*** (interviews with top researchers on hot topics in microwaves) with UCLA's Aydin Babakhani and Princeton's Kaushik Sengupta in volume 1; and (3) ***Women in Microwaves***, with a special featured Microwave History Project interview with UC Davis Chancellor Emeritus and noted microwave antennas and circuits analyst, Linda Katehi.

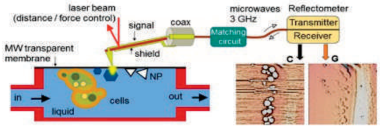


Microwaves are Everywhere: CMB, in Inaugural Issue 2021

Microwaves are Everywhere: Ovens from Magnetrons to Metamaterials, in April 2021



Microwaves are Everywhere: RFID tags, in July 2021



Microwaves are Everywhere: nano – Microwaves, in October 2021

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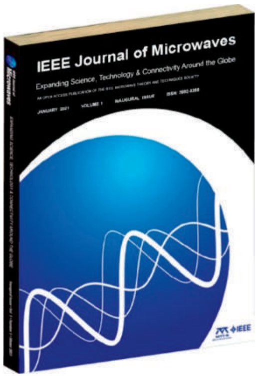

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Cognitive Electronic Warfare: An Artificial Intelligence Approach

Karen Zita Haigh, Julia Andrusenko

This comprehensive book gives an overview of how cognitive systems and artificial intelligence (AI) can be used in electronic warfare (EW). Readers will learn how EW systems respond more quickly and effectively to battlefield conditions where sophisticated radars and spectrum congestion put a high priority on EW systems that can characterize and classify novel waveforms, discern intent and devise and test countermeasures. Specific techniques are covered for optimizing a cognitive EW system as well as evaluating its ability to learn new information in real time.

The book presents AI for electronic support, including characterization, classification, patterns of life and intent recognition. Optimization techniques, including temporal tradeoffs and distributed optimization challenges are also discussed. The issues concerning real-time in-mission machine learning (ML) and suggests some approaches to address this important challenge are presented and described. The book covers electronic battle management, data management and knowledge sharing. Evaluation approaches, including how to show that an ML system can learn how to handle novel environments, are also discussed. Written by experts with first-hand experience in AI-based EW, this is the first book on in-mission, real-time learning and optimization.

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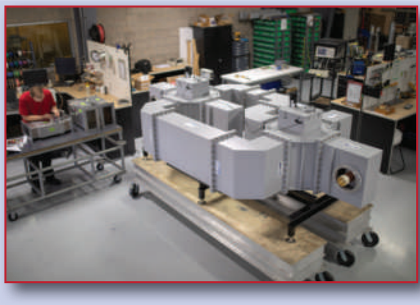
FABS and LABS

Microwave Techniques Defines High Power



There's power and there's power, like thousands of watts to megawatts. Microwave Techniques LLC is one of the few companies dedicated to truly high power RF, microwave and mmWave components and systems for defense, industrial, medical, scientific and broadcast. The parent of several companies, Microwave Techniques' brands are well known: Mega Industries, Ferrite Microwave Technologies (FMT), Industrial Microwave Systems (IMS), Micro Communications (MCI) and FXR Microwave. In addition to focusing on high power, Microwave Techniques differentiates itself by offering both components and systems.

Its extensive portfolio of high power components includes circulators, isolators, loads, waveguide and coaxial transmission lines, combiners, stub tuners, filters, coaxial transfer switches and vacuum components, some with power handling to 50 MW and covering frequency bands from 50 MHz to 50 GHz.

The systems offered by Microwave Techniques perform microwave tempering for frozen foods and meats; cooking pre-cooked foods like bacon; heating and drying foam, wood and textile materials; cylindrical heating of fluids, liquids and chemicals; and generators and transmitters for various applications. These industrial systems typically operate in the 915 MHz ISM band and generate power levels from 6 kW to 1.2 MW, tailored for the application.

Each company in Microwave Techniques' portfolio has a long heritage serving its market. MCI formed in 1966 to develop components for broadcast transmitters, like coaxial transfer switches and combiners. It has the distinction of receiving two Technology & Engineering Emmies, recognizing it for RF combiner innovation and pioneering broadcast transmission technology.

Started in 1983, FMT was a spin-out from Raytheon's Special Microwave Device Operation, formed to supply industrial microwave systems. FMT adopted a vertical integration strategy, developing and manufacturing the high power components used in its systems, except for high power tubes. It also uses this capability to increase manufacturing volumes by selling high power components.

Prompted by customers, Mega Industries started in 1989 with a team of three working in a 2500 square foot "garage" in Portland, Maine. Its heritage is found in many high energy physics laboratories around the globe: the Large Hadron Collider at CERN, the European Spallation Source at Lund, the SLAC National Accelerator Laboratory in Menlo Park.

Today, Microwave Techniques has facilities in Maine, New Hampshire and North Carolina. The components division (the FMT, Mega, MCI and FXR segments) occupies two facilities in Gorham, Maine. Last February, the company expanded to support growth from the 2020 Mega-FMT merger. Adding 21,360 square feet, the components division now has nearly 60,000 square feet for manufacturing, testing and assembly. This includes an ISO Class 5 clean room for cleaning, brazing and assembling ultra-high vacuum components, constructed in 2013. The expanded facility also houses sales, engineering and administration. Systems manufacturing is based in Nashua, New Hampshire. To add manufacturing capacity to support growth and the recent acquisition of IMS, the systems division will move to a larger facility this fall. IMS' North Carolina site will remain as an R&D center, developing 915 and 2450 MHz heating systems.

Although its products may be considered mature, Microwave Techniques has the latest design tools for product development: CST Microwave Studio, Ansys HFSS and SolidWorks for mechanical and thermal analysis. Additive manufacturing is used for some manufacturing operations, complementing conventional machining.

Now with more than 100 staff, Microwave Techniques retains a small company culture based on open communication and teamwork. To maintain the expertise gained over the decades, the company has established an apprentice program, teaming experienced and new staff, recent high school and college graduates.

Very high power RF is something of a hidden market, yet its many applications are found throughout modern life, from scientific research to consumer food preparation. Microwave Techniques knows this market "second to none," demonstrated by its long-term commitment to meeting each customer's unique needs. "Our engineering team can handle any project that comes our way."

www.microwavetechniques.com

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- 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

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