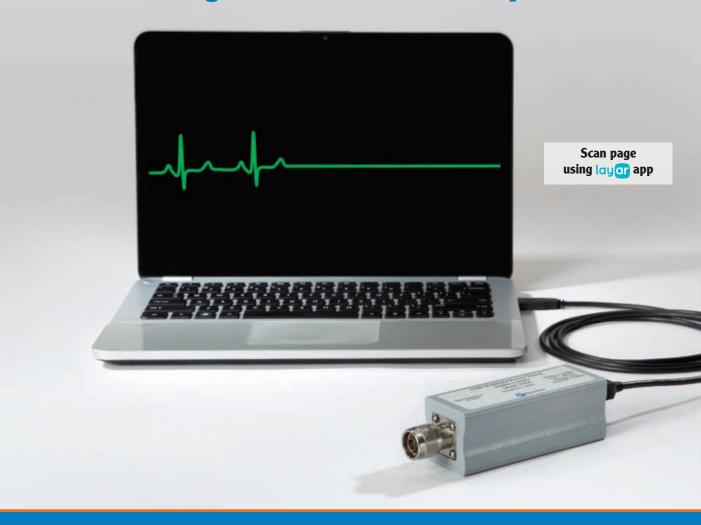


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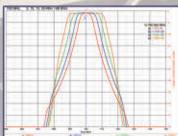
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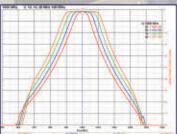
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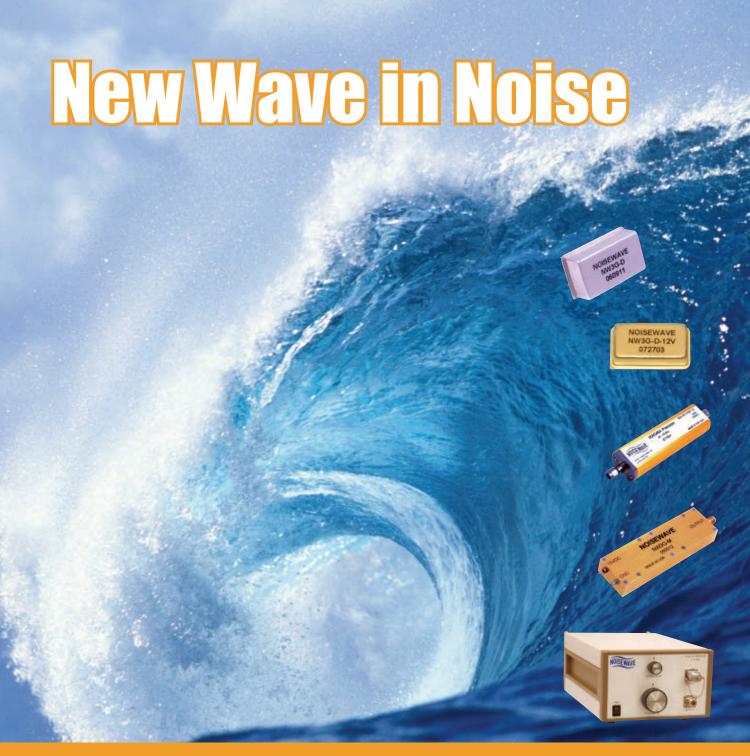


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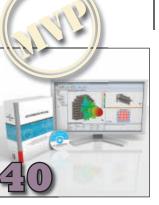
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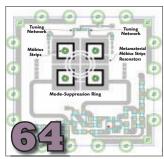




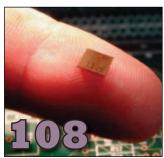


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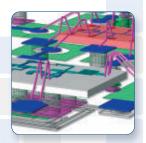
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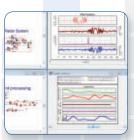
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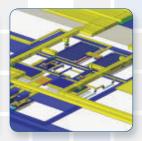
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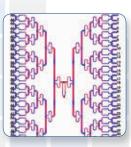


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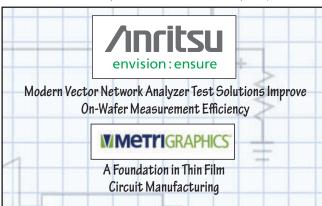
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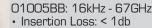
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very year, we make a few design changes to the magazine, ⊿add new features to our online products and expand our event presence. This year is no exception. You'll find a new look on several of our pages, including the "Mark Your Calendar" page and the inside back page, which features a new "Fabs and Labs" series that highlights companies with interesting design, fabrication, assembly and test facilities that our editors visit during their travels around the industry. This series will run intermittently during the year, rotating with the "STÉM Works" feature that debuted in 2014. We have also added a fourth special supplement, focused on "Aerospace & Defense Electronics," which will be mailed with our May issue. If you have not renewed your subscription lately, I hope you'll do so soon. It's free; all we ask is two minutes of your time to update your profile.

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It's an exciting year for events. In the first quarter alone, you'll find MWI editors at DesignCon (Santa Clara, Calif.), Mobile World Congress (Barcelona) and Satellite (Washington, DC). April brings us to Microwave & RF (Paris), WAMI-CON (Cocoa Beach, Fla.) and EDI CON China (Beijing). The IEEE MTT-S IMS takes place in May in Phoenix this year, so our show issue will be in April and not the usual May. The European Microwave Week event is also earlier this year, taking place in September in Paris. Our August issue will serve as the preview for EuMW. Paris is always a good venue for this annual event, so I expect an excellent turnout this year. I'm also looking forward to the return of the IEEE COMCAS event in Tel Aviv in November. Microwave Journal will be coordinating the Publicity for COMCAS, so look for updates as the year progresses.

EDI CON China has moved to the new China National Convention Center in Beijing this year. The event will take place on April 14–16 and features a larger exhibition and expanded conference, with a 5G track added to the schedule. Many of the leading test and measurement, semiconductor and component manufacturers will be showcasing their products and technologies on the show floor and in the conference through submitted papers and workshops. This event is unique in that it is industry-driven, with practical information for working

engineers. The conference and exhibition are synergistic and focused on the needs of the audience.

Looking further ahead, I'm pleased to announce that the EDI CON event will make its debut in the U.S. next year. We're taking the model that has proven so successful in China to Boston in September, 2016. We have the perfect venue, in the heart of the city, during the nicest time of the year in New England. That's right – you can come to Boston, learn the latest design techniques and technologies while enjoying the local attractions of Boston and the spectacular fall foliage. Stay tuned for more details during the year.

This issue of Microwave Journal has an editorial focus on "Radar and Antennas," featuring a very interesting cover story on "Wideband Omnidirectional Microwave Cloaking." The Romulans would be proud of the work of author Nathan Cohen of Fractal Antenna Systems. Also featured is the third and last in the special report series from distinguished authors Ulrich Rohde and Ajay Poddar on their research on Möbius Metamaterial and Strip Resonators. This series of articles has generated a lot of attention and positive feedback from our readers. In the MVP. CST unveils its "STUDIO SUITE 2015" and the lineup of technical features includes several theme-related topics. There's something for everyone, including a recap of our recent visit to the "new" Keysight Technologies headquarters.

Thanks for reading and wishing all of you a successful year ahead! ■



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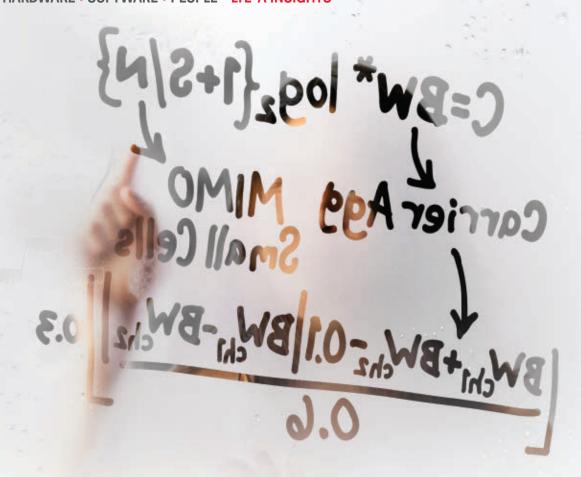
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Wideband Omnidirectional Microwave Cloaking

Nathan Cohen

Fractal Antenna Systems, Bedford, Mass.

Scattering from electrically large objects invites discussions of Mie versus Rayleigh, shadows and diffraction, side scatter and backscatter. But one attribute remains infrequently discussed: forward or "front" scatter. Antipodal transmission, the continuation of the transmitted wave with fidelity to the other side, is a puzzle posed by blockage and failure to find a way to fully propagate waves around it. If robust front scatter is possible, and the surface orientation is not prescriptive, the object itself becomes hidden, cloaked by the mirage of the environment on the other side. The object is invisible. Such a phenomenon is not a natural occurrence and requires new technology to approximate and achieve realization.

hile invisibility has always been a fantasy of fiction for many,1 engineering has developed limited alternatives with camouflage or stealth methods that absorb, reflect or directionally side-scatter waves to block the appearance of objects and render them less visible.^{2,3} Although many of these methods are ambiguously described as cloaking, they do not uniformly propagate front scatter without a preferential orientation, nor do they employ front scatter as a dominant mechanism. This article summarizes the results of the first true cloaking,4-6 demonstrating microwave cloaking with wideband performance, a dramatic decrease of side and backscatter, no preferred angular orientation in azimuth and robust front scatter.

EVANESCENT SURFACE WAVES

Applications of the near field still render some surprising advantages, the most recent being associated with evanescent surface waves (ESW), also called plasmonics.^{7,8} ESWs are produced by impinging radiative traveling

waves upon resonators and dielectrics in close electrical proximity to conductors, including other resonators. By their nature, ESWs dominate electromagnetic transmission with close resonators, usually with less than $\lambda/10$ separation. Electromagnetic waves jump from one resonator to the next and remain on the surface. When such circuits are closely packed, they are also called metamaterials, whereas when they are more widely spaced, they have limited ESW transmission and are often called frequency selective surfaces.⁹ Metamaterial performance has previously been limited by the footprints and passband responses of the resonant structures used, which are typically split ring resonators. Such resonators are high Q but moderate in size, thus constraining their packing ability and limiting the efficiency of ESW transmission.

Fractals offer a unique opportunity as antennas and resonators, based on their multiband or broadband performance, small size, absence of LC components and efficiency. ¹⁰⁻¹² A good example with an excellent tradeoff of

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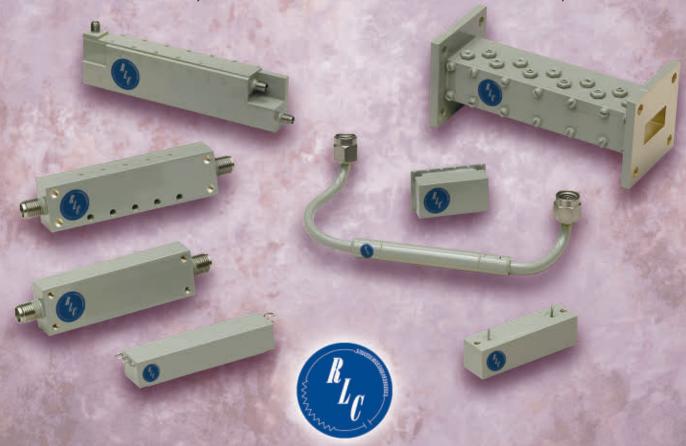
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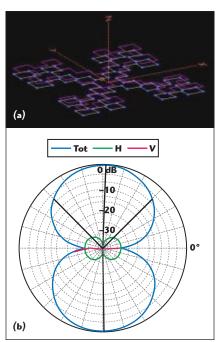
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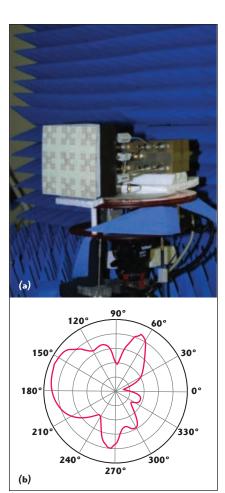


▲ Fig. 1 Minkowski loop fractal antenna model with amplitude of the two current maxima (a) and power pattern at lowest resonant frequency (b). Gain is within 0.2 dB of a dipole (copper losses included).

characteristics is a Minkowski fractal antenna, ¹⁰ shown in *Figure 1*. The small footprint, about $\lambda/8$ on a side at the lowest resonant frequency, yields a highly efficient figure-eight dipole pattern with excellent polarization integrity. It also has multiple non-harmonic resonances that make a "passband meld" for broader bandwidth at the lower frequencies and a continuous broadband characteristic at higher frequencies. ¹³⁻¹⁵ Thus, it has been used in close packed arrays, where ESWs are expected to be important.

ESWs on a fractal array were first demonstrated in $2001.^{16}$ This is reproduced in Figure 2a, showing a 3 × 3 array of Minkowski fractal elements¹⁰ shaped as loops that is corporate fed with an element spacing of about $\lambda/14$. Each element falls within a footprint of approximately $\lambda/8$ at the lowest resonant frequency, and the array is offset slightly in azimuth to facilitate measurements on the plane. A metal backplane with roughly $\lambda/8$ air dielectric separation is behind the array, acting as the boundary condition required in plasmonics to give rise to ESWs.

The azimuthal power pattern (see *Figure 2b*) is notable as showing super gain, but the interest here is focused on the 90 degree lobes. These



▲ Fig. 2 Fractal array (a) and power pattern with ESW lobes (b).

lobes are caused by ESWs with intensities that rival those of the main lobe. The ESWs terminate at the array edge and become propagated radiated waves.

This demonstrates that for close packing, less than $\lambda/10$, ESW effects become appreciable in fractal metamaterial arrangements. It also shows that fractal structures, being far smaller than conventional designs and with no additional components attached, are natural to use if these effects are desired. The strong ESWs from these fractal metamaterials poses an opportunity to explore applications where ESWs may be needed, including cloaking.

RECIPE FOR A CLOAK

A cloaking mechanism must have the ability to passively guide far field traveling waves around an object or utilize ESWs to do so. Mirrors and lenses can be used to satisfy the former, but like the magicians' invisibility illusion, they require very specific



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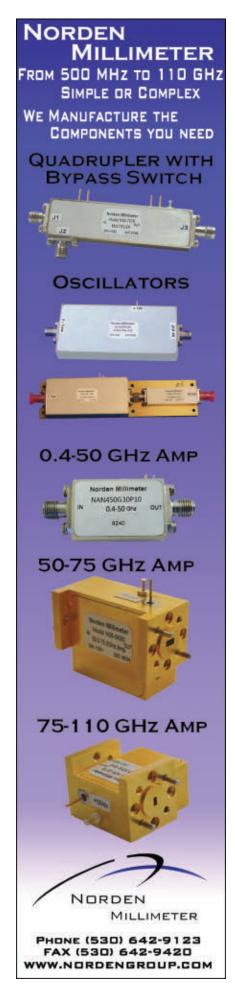
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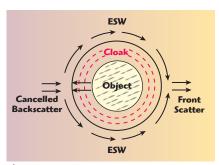


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▲ Fig. 3 Cloak concept showing front and back scatter.

orientations or cannot entirely hide the blocked object. A cloak exploiting ESWs does not suffer from these hindrances.

Far field traveling waves impinge on a metal-backed metamaterial, producing ESWs. Care should be taken so that the resonators are wideband and closely packed (that is, a fractal metamaterial). The metamaterial array, which can be constructed in closed-surface layers, cloaks the object housed within the metal backing, for example, a metal cylinder. Any object of any composition may be considered cloaked inside that region. In addition, when properly spaced, the far field traveling wave reflects in backscatter and combines out of phase with its own impinging wave, yielding phase cancellation. There is also an attenuation of side scatter, as the ESW propagate on the surface, with little, if any, radiating wave in the far field.

If the cloak's surface is closed, then at the antipodes of the impinging wave, the ESWs combine and produce a radiating traveling wave emerging from the plane of the surface in a reversal of their production. With no impinging radiating traveling wave on the "front" side, the produced radiating traveling wave does not have a second wave with which to combine and phase cancel. It constitutes front scatter of the wave which impinged from the opposite side, as shown in **Figure 3**.

From a construction standpoint, a cloak is thus a closed surface structure composed of an array of fractal metamaterials, dielectric and a metal inner sheet. *Figure 4* shows the outer layer of a simple two-layer cloak. Note the closely packed Minkowski fractal resonators, with a slight modification to the design for better packing. Material and structural information is given in *Table 1*.



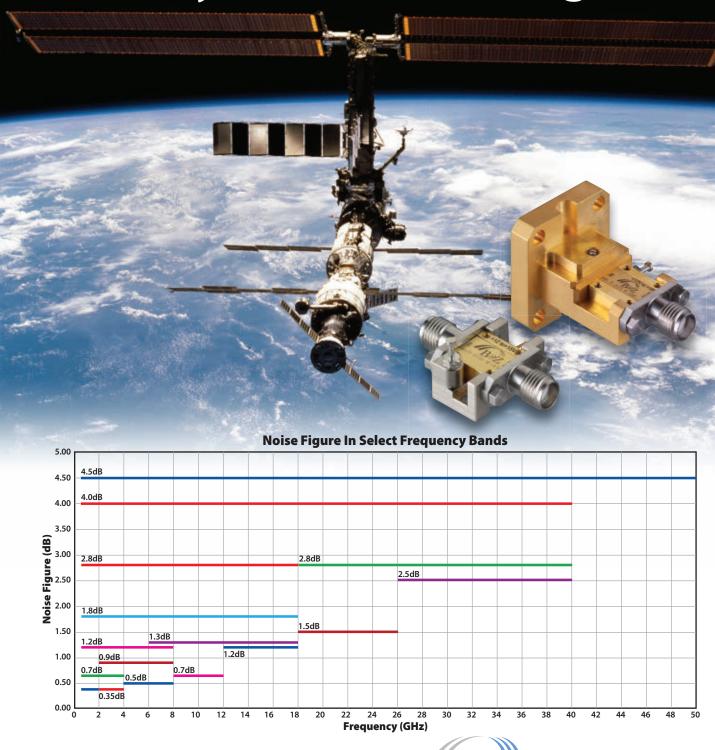
Fig. 4 Outer layer of a simple two-layer cloak for microwaves.

TAE	BLE 1
020000000000000000000000000000000000000	ER MATERIAL AND INFORMATION
Material	RF35 PCB with Minkowski fractal traces
Separation of layers	1 inch
Height	15.3 inches
Outer diameter	11 inches
Spacer dielectric	Air foam
Object diameter (max)	6 inches
Fractal loop	Modified Minkowski ⁵

Other phenomena support this cloaking approach. For example, Chandran, et al., ¹⁷ reported highly reduced backscatter in metal-backed fractal surfaces, evidence for reflected and impinging radiated wave cancellation during backscatter. This reflection approach is an extrapolation of Jaumann absorbers, but the ease of realization with fractal structures was not anticipated.

A cloak attempt by Schurig, et al., ¹⁸ demonstrating a lossy, high Q device with moderate shadowing, is believed to result from transformational optics. Transformational optics must be considered a generic term without invoking a specific radiative transport mechanism, and ESW transport falls within that category. Yet the failure of that device to exclude diffraction as a mechanism for the attenuated, narrowband front scatter leaves the success of that as a bona fide cloak ambiguous. ¹⁹

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SIMPLE CLOAK

Before advanced cloaks with precise imaging properties and visual light abilities (the fantasy of science fiction) are realized, it is necessary to demonstrate the ability to produce even the simple cloak illustrated in Figure 3. The approach is to use the microwave spectrum for construction simplicity of electrically thin cloak layers and a simple closed-surface geometry. First accomplished in 2008,^{4,5}

this version of the simple cloak is sufficiently large to cloak 3D objects and to accomplish measurements with L-Band equipment.

Structural symmetry is not a restriction for cloaking: only a closed surface is needed to assure antipodal transmission of front scatter. However, for illustration, cylindrical symmetry limits the number of variables which might otherwise obscure understanding the ESW effects. Thus the results

will be independent of the azimuthal rotation of the cloak itself: there is no specific requirement of preferred azimuthal alignment.

Measurement employs two log periodic antennas at sufficient separation so that the cloak fills the beam vertically.6 Since the horizontal portion of the beam is far wider, the cloak cannot fully fill the beam in that direction, so some coverage extends beyond the cloak, limiting the degree of blockage by an object to be cloaked and the dynamic range to roughly 25 dB or less. Polarization is taken as linear vertical, with the cloak oriented as a vertical cylinder. The cloak is electrically large, and the lower cutoff is limited to 700 MHz, where the height is approximately one wavelength.

A vector network analyzer made the S12 measurements. All gain data is normalized to the direct path, that is, two antennas on opposite sides of the cloak's center position (zero degrees in azimuth) with no blockage or cloak present. While these measurements are with the vertical polarization along the major axis of the cloak, the loop configuration of the fractal metamaterial resonators is agnostic to polarization orientation.

With no cloak or other objects present, this yields a 0 dB reference line at all frequencies. Then the cloak is introduced, using an internal metal pipe to be cloaked, as an example. This is shown in *Figure 5* (see video at www.



▲ Fig. 5 Placing the cloak over a metal cylinder (pipe) to be cloaked.

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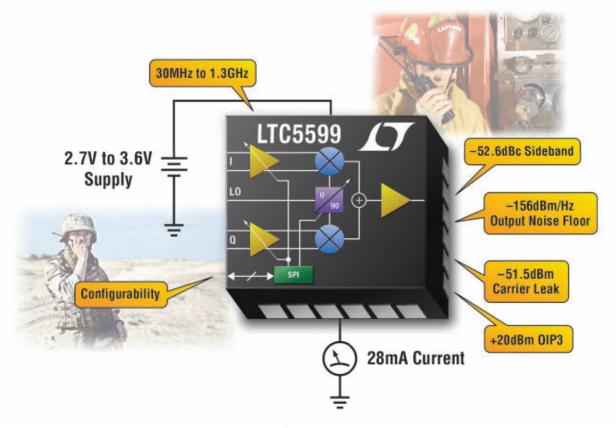
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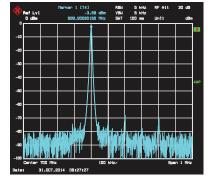
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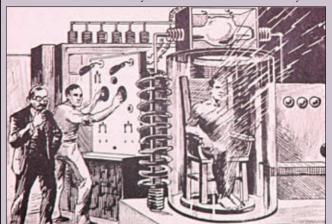
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SIDEBAR

First Person Cloaked

To the general public, rendering a person invisible is the stuff of Star Trek, Harry Potter and H.G. Wells (see **Sidebar 1**). But beyond the dreams and fantasy, the



▲ Sidebar 1 1930s pulp sci-fi illustration shows a man in a cylinder dematerializing and becoming invisible.



▲ Sidebar 2 Cloaking of an engineering intern.

quest for human invisibility poses technical challenges and compelling examples of electromagnetics. Furthermore, it sets the bar for future cloaking efforts.

In August 2012, to commemorate the issuance of the world's first true invisibility cloak patent and serve as a symbol that the path of this new field rests on the shoulders of those who grew up during the wireless revolution,

the team at Fractal Antenna Systems scaled up a two-layer microwave cloak to make an engineering intern disappear (see *Sidebar 2*).

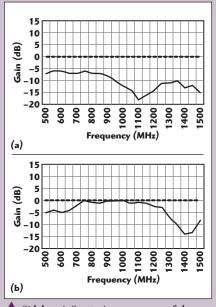
The human cloak. illustrated in **Sidebar 3**, is electrically larger in size, has a larger cloaking volume, greater nal to noise ratio and higher fidelity, compared with the smaller cloaks previously built. It simply consists of a thin copper cylinder, two fractal metamaterial layers, air foam spacers and an RF transparent support structure.

Sidebar 4a shows the direct path with no obstruction (dotted line) compared with the intern crouched and blocking the path of radiation (solid line). Sidebar 4b compares the same direct path to the

BIGGIE CLOAK
PRACTALS

BIGGIE CLOAK
PRACTALANTENNA SINTENNA
CLOAK
(FRACTALS)

Sidebar 3 Design of a large cloak.



▲ Sidebar 4 Scattering responses of the uncloaked intern compared with the direct path (a) and the cloaked intern compared with the direct path(b).

path with the cloak placed over the crouching intern. Note the transmission "through" the intern (solid line), demonstrating ESW-enabled front scatter with the cloak on. The intern has "disappeared" over a broad frequency range centered at 1 GHz.

Visit www.mwjournal.com/cloaking for more demos.

mwjournal.com/cloakingvideo1). The pipe alone blocks the signal by more than 10 dB at some frequencies. With the cloak covering it, however, front scatter gain is returned to 0 dB over a broad frequency range from about 700 to 1400 MHz. The cloak diverts transmission around the pipe and produces front scatter.

The cloak performs the same under rotation, with both antennas fixed on opposite sides. The rotation of the cloak in azimuth, with the antennas held stationary, produces virtually no change to the front scatter gain, as expected. There is no preferred orientation in azimuth. This, along with dramatic enhancement of front scatter and reduction of side and backscatter are the key characteristics of true cloaking.

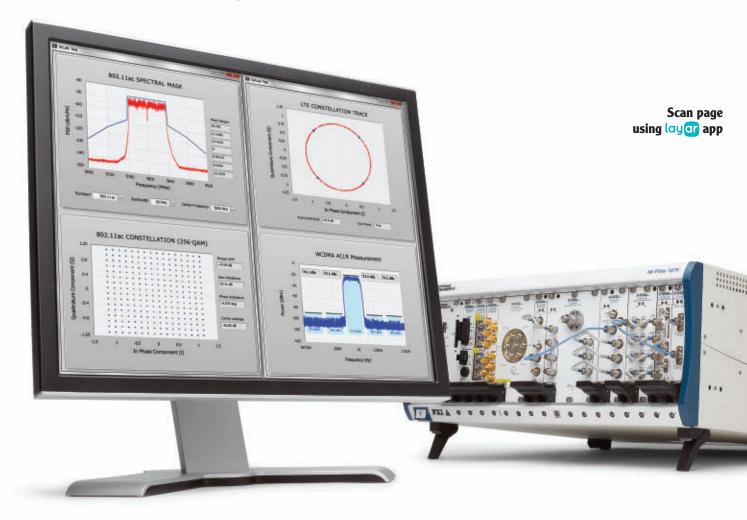
As in all experimental measurements, a control is essential. Here, it is the replacement of the entire cloak by a metallic 'copper' cylinder of the same size. In the video, this is done by covering the outer cloak layer with aluminum foil. For multiple measure-

ments at different azimuthal angles of the two antennas, a copper-clad cylinder control is placed next to the cloak itself (see *Figure 6*).

The data shows the effects of the cloak on front scatter and backscatter. Starting with the control 'copper' cylinder directly blocking the direct path between the two antennas, we expect the front scatter to be greatly reduced, and the backscatter to be greatly enhanced from specular reflection. In such measurements the antennas are on opposite sides of the

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▲ Fig. 6 Cloak (left) and copper cylinder used as a control (right).

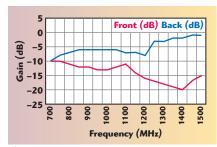
cloak or copper for front scatter, and next to each other, on the same side, for backscatter. Again, using the direct path normalized at 0 dB, the response of the control for front and backscatter is shown in *Figure 7*. As expected, backscatter is present, approaching a gain nearly that of the direct path, while the front scatter is significantly lower.

Placing a cloak with the pipe as an object in place of the control cylinder

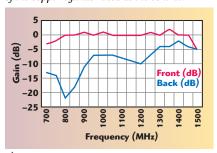
yields the exact opposite; backscatter is reduced and front scatter is enhanced (see Figure 8). Front scatter now closely tracks the direct path intensity over a frequency range of approximately 700 to 1400 MHz, a 2:1 bandwidth. In other words, we are are "seeing through to the other side" with excellent amplitude fidelity. Note that the backscatter is dramatically reduced from about 700 to 950 MHz, with a minimum at about 825 MHz. The Q is higher (about 30 percent bandwidth) for the backscatter because the reflected traveling wave has only one main layer to reflect from; additional fractal metamaterial lavers would substantially increase the bandwidth to minimize back scatter.

With the minimum backscatter at 825 MHz, a full azimuthal scan of the antenna at that frequency is useful to compare the overall scattering behavior of the cloak versus the control. Because the log periodic antennas have wide beams, baffles were used to suppress off-angle coupling and measurements were done by moving one antenna in 30 degree steps, starting with the direct path at zero degrees. The cloak and control, when measured, do not change their positions; only the antenna angles relative to the center point of the cloak's placement change.

To understand how these measurements relate to scattering, side scatter is sampled at angles near 90° and 270°, while backscatter is near 180°:



▲ Fig. 7 Front and back scatter measurements of the copper cylinder used as the control.



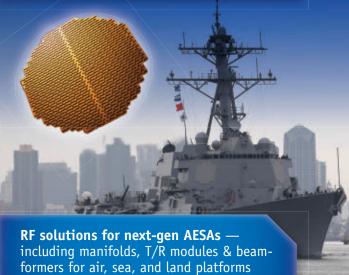
▲ Fig. 8 Front and back scatter measurements of the cloak with internal pipe.







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and front scatter is near 0° in azimuth. The values at 180° are approximated to be 183° and 177°, respectively, as the baffle prevents the two antennas from being placed at the same position simultaneously.

The two antennas without any cloak or obstruction are measured over the full azimuthal range of their differential angular placement (direct). This represents the response of the antenna system, with the baffles and other (minor) reflections present,

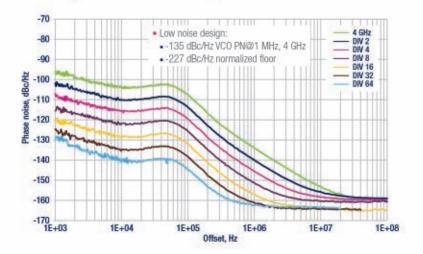
without a blocking object, cloak or control. Next, at each differential azimuth angle, the cylinder (copper) and then cloak-on-pipe (cloak) are measured, yielding a total of three measurements per azimuth sample. This allows an unbiased comparison of the cloak and copper. A polar plot of the data is shown in *Figure 9*.

The cloak scattering response closely matches that of the azimuthal response of the antennas alone, without any cloak or obstructions. The

front, back and side scatter all act as if there is nothing there. In contrast, the copper control shows very little front scatter (as in Figure 6), and substantial side and back scatter. The lobe-like pattern is produced by the variation in response from baffle placement with changing azimuth. A marked difference between the control and the cloak, with a close match of the cloak to the direct measurement, is compelling evidence for cloaking by the enhancement of front scatter and the reduction of side and backscatter.

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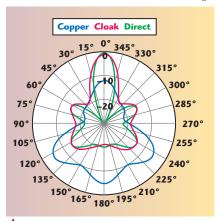
NEXT STEPS

This simple cloak establishes the value of using ESWs for cloaking with fractal arrays as the enablers. With cloaking realized, questions and issues become varied and numerous. In fact many have already been addressed by the author and will be discussed in future publications. It is helpful to enumerate these issues as next steps.

Large object, thin cloak: Much larger microwave cloaks have been built and function successfully. The largest cloak yet devised successfully cloaked a person, realizing H.G. Well's historic fantasy. The sidebar (see page 32) describes that effort. The cloak is a thin skin on a large cloak because the cloaking layers depend on wavelength separation, not scaled-size ratios.

Tunneling and object-view non reciprocity: Seeing out of a cloak from inside is not the reciprocal action of external cloaking. However, having a copper or metal barrier certainly stops the action. This has been overcome with a fractal screen as the inside barrier rather than a solid metal sheet.²⁰

Reduced backscatter and op-



▲ Fig. 9 Azimuthal scattering from the control and the cloak.

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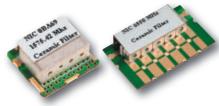
LC Filters



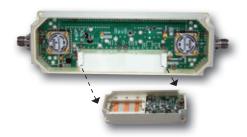
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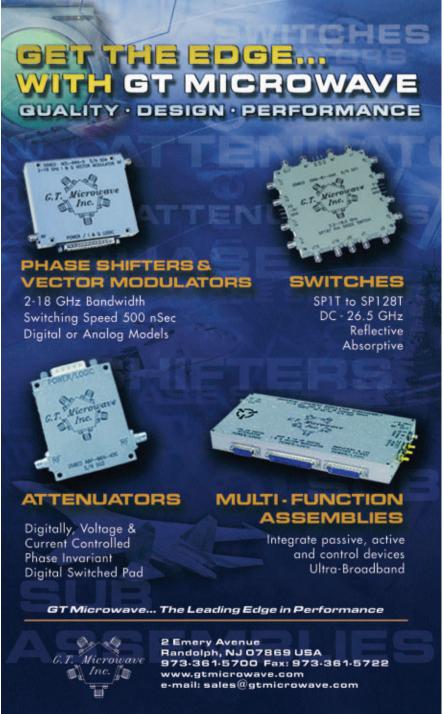
CoverFeature

timization: Cloaking may achieve wideband and significant backscatter reduction by optimizing the cloak parameters and by adding layers. This awaits a defined need.

Diverted imaging: Antipodal transmission implies origin symmetry of the image. Whether this will limit cloaking, ultimately, as an optical camouflage method will depend on the understanding of cloaking as an imaging system, rather than the radiometric one discussed here.

Non-symmetric surface cloaking: Surface symmetry (as in cylinders or spheres) is not a requirement for cloaking and cloaking with asymmetric surfaces has been demonstrated.²⁰

Visual light and infrared cloaking: The patterning of resonators is easily achieved at infrared wavelengths but this may prove challenging at optical wavelengths for any large surface. Additional manufacturing developments may warrant interest in the "Harry Potter" effect when this is achieved.



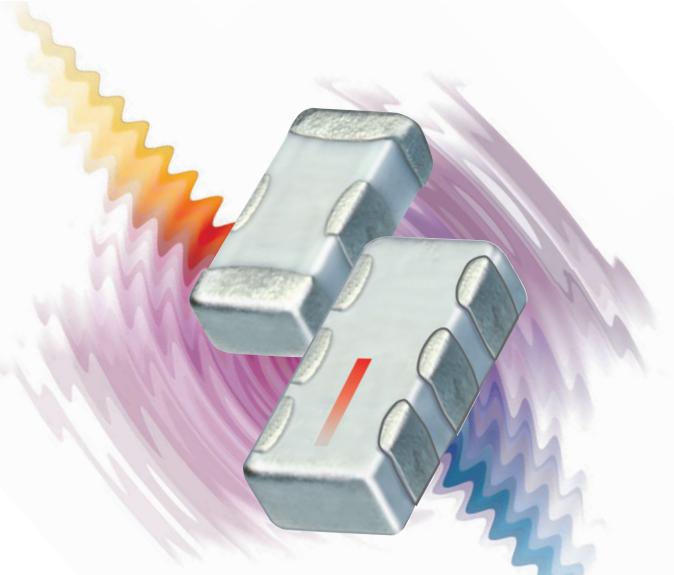
CONCLUSION

The first true cloaking system uses ESWs to produce substantial front scatter over a wide bandwidth and reduced backscatter and side scatter, with no preferential angular orientation of the cloak's surface. Far from science fiction, the world of invisibility looms ahead, neither blocked by an absence of mechanism nor totally transparent in its use and implications.

References

- H. G. Wells, "The Invisible Man," Pearson, London, 1897.
- 2. K. Vinoy and R. Jha, "Radar Absorbing Materials," Kluwer, Boston, 1996.
- 3. G. Ruck, D. Barrick, W. Stuart and C. Krichbaum, "Radar Cross Section Handbook," Plenum, New York, 1970.
- N. Cohen, "Fractal Antennas and Fractal Resonators," U.S. Patent 7,256,751, 2007.
 N. Cohen, "Wideband Electromagnetic Invis-
- N. Cohen, "Wideband Electromagnetic Invisibility Cloak," U.S. Patent 8,253,639, 2012.
- N. Ćohen, "Body-Sized Wideband High Fidelity Invisibility Cloak," Fractals, Vol. 20, November 2012, pp. 227–232.
- R Maier, *Plasmonics*, Springer, New York, 2007.
- S. Zoughi, A. Sihvola and A. Vinogradov, "Metamaterials and Plasmonics: Fundamentals, Modelling, Applications," Springer, Dordtrecht. 2008.
- B. Munk, "Metamaterials: Critique and Alternatives," Springer, Dordtrecht, 2008.
- N. Cohen, "Fractal Antennas Part 1", Communications Quarterly, Vol. 5, No. 3, Summer 1995, pp. 7–22.
- 11. N. Cohen, "Fractal Antennas and Fractal Resonators," U.S. Patent 6,452,553, 2002.
- A. R. Harish, A. Agarwal, N. Kuchhal and V. Jain, "Compact Loop Antennas and Arrays," Proceedings of the International Conference on Antenna Technologies, 2005, pp. 531-535.
- N. Cohen, "Fractal Antennas Part 2," Communications Quarterly, Vol. 6, No. 3, Summer 1996, pp. 53–66.
- N. Cohen, "Practical Introduction to Fractals: Antennas and Beyond Part 1," Proceedings of the Radio Club of America, Spring 2014, pp. 12–18.
- A. Raveendran, "A Study on Minkowski Fractal Wideband and Multiband Antenna," M.S. thesis, Texas A&M University, 2012.
- N. Cohen and R. Hohlfeld, "Close-Packed Fractal Antenna Array," AFRL/SNRT Contracts F30602-02-M-V042V-034, 2002.
- A. R. Chandran, T. Matthew, C. K. Aanandan, P. Monahan and K. Vasudevan, "Low Back-scattered Dual-Polarized Metallo-Dielectric Structure Based on Sierpinski Carpet," Microwave and Optical Technology Letters, Vol. 40, No. 3, February 2004, pp. 246–248.
- Vol. 40, No. 3, February 2004, pp. 246–248.

 18. D. Schurig, J.J. Mock, B.J. Justice, S. A. Cummer, J.B. Pendry, A.F. Starr and D.R. Smith, "Metamaterial Electromagnetic Cloak at Microwave Frequencies," *Science*, Vol. 314, No. 5801, November 2006, pp. 977–980.
- J. B. Pendry, D. R. Smith and D. Schurig, "Electromagnetic Cloaking System." U.S. patent application 20080024792 (examiner's comments in rejection), 2008.
 N. Cohen, "Additional Advances in Cloaking
- N. Cohen, "Additional Advances in Cloaking Using Fractal Resonators," in preparation, 2015.



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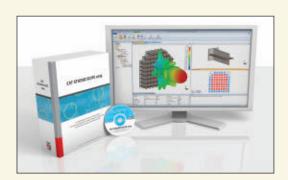
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Simulation helps engineers analyze and optimize products, while synthesis software helps them select and create designs. Alone, these are powerful tools for the development of any electromagnetic device. Combined, they complement and strengthen each other. With the release of the CST STUDIO SUITE® 2015, synthesis, design and optimization are now more tightly integrated into the simulation workflow.

New design tools for filter synthesis, phased array creation and decoupling capacitor optimization supplement the tight integration with the antenna synthesis tool, Antenna Magus, and the matching circuit synthesis tool, Optenni Lab. New, fully parametric import options from leading computer-aided design (CAD) software allows CST STUDIO SUITE to be integrated into a wide range of external workflows.

PHASED ARRAY WIZARD

Although complex to design, phased arrays offer excellent performance and beam steering. For engineers working on array design, CST STUDIO SUITE 2015 introduces the Phased Array Wizard. This tool helps design both the individual element and the full array layout, in a single smooth workflow.

First, a unit cell simulation calculates the performance of the individual elements, including the active element impedance and pattern. These are used to optimize the element across all scan angles and frequencies, and array performance is estimated from the array factor.

Once the element is designed, the full array is created. The user defines the excitation and layout, including passive elements, and the Phased Array Wizard automatically creates a full 3D model of the array, including the feed, mounting brackets

and radome. The simulation also produces a field source for analysis of installed performance.

FILTER DESIGNER 2D

The recent addition of Filter Designer 2D (FD2D) to CST STUDIO SUITE significantly improves planar filter design. FD2D is based on trusted, mature filter synthesis technology from Nuhertz and is directly integrated into CST STUDIO SUITE. The user specifies the filter requirements, and FD2D recommends suitable topologies. Users compare these suggestions to find the filter type that best suits their needs.

Once the filter is selected, FD2D automatically exports the filter schematic directly into the simulation project. Filters can be integrated into larger devices and simulated with the circuit simulation tools included in CST STUDIO SUITE. Planar filters can be automatically assembled in full 3D, allowing users to fine tune the design, investigate installed performance and calculate thermal detuning.

PARAMETRIC IMPORT TOOLS

Increasingly, CAD tools are becoming full project managers, capable of storing vast amounts of information about the design project. To improve integration with these powerful tools, CST STUDIO SUITE 2015 supports fully parametric import from SOLIDWORKS 2013 and PTC Creo™ Elements™ 5.0. Models that are imported include the design parameters that have been defined, making it easier to incorporate simulation into the design process.

COMPLETE NEAR FIELD SOURCE COUPLING

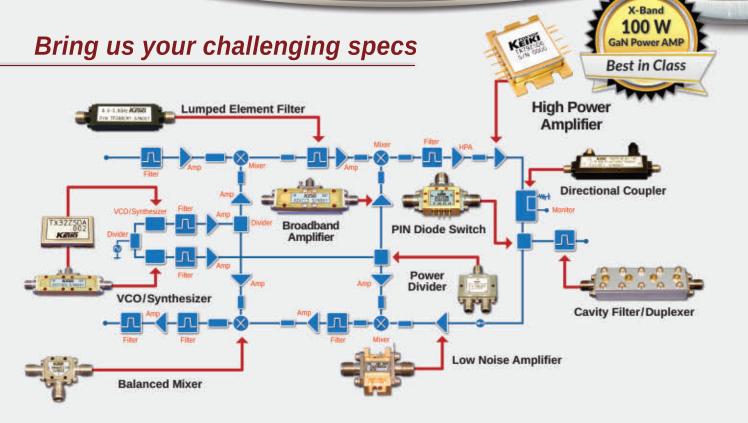
Excitation using near field sources to the frequency domain solver and the asymptotic



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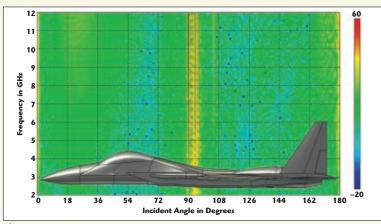








Most Valuable Product



▲ Fig. 1 RCS map for an aircraft.

solver is included. This means all of the general-purpose high frequency solvers in CST STUDIO SUITE are fully compatible, enabling hybridized simulation for a wide range of applications.

For example, it is now possible to use inward-facing near field sources from a complex device to irradiate a single component in the frequency domain solver or to use the near field of an antenna as the excitation for an installed performance simulation using the asymptotic solver. Measured near field sources can be used with these solvers, allowing physical components to be incorporated into virtual prototypes.

RADAR CROSS SECTION

Radar cross section (RCS) has long been a major application for CST STUDIO SUITE, and the 2015 release introduces several new features that further increase RCS capabilities. The asymptotic solver now supports frequency, angle and polarization dependent radar absorbing material (RAM), allowing these coatings to be simulated more accurately.

The solvers now automatically produce RCS maps – plots of RCS versus incident angle and frequency, as shown in *Figure 1* – that help identify the causes of scattering.

PCB SIMULATION

When designing PCBs and packages, a full 3D simulation is often necessary to understand the behavior of the board, components and housing. Discretizing a complex multilayer board accurately is time consuming, so a new tetrahedral meshing technique optimized specifically for printed structures has been developed. This algorithm intelligently identifies and meshes standard structures such as signal lines, reference planes and vias. For complex packages, it can reduce meshing time by more than 85 percent.

Also, the placement of decoupling capacitors can now be optimized automatically with the Pareto frontier optimizer (see *Figure 2*). This balances cost with performance and helps find the most cost-effective solution to power integrity issues.

QUAD MESHING

The integral equation solver and the multilayer solver, respectively used to simulate electrically large and planar structures, have improved performance due to the new quad-based surface mesh. Using quadrilaterals instead of triangles, the new mesh reduces the number of unknowns and reduces simulation time.

HIGH PERFORMANCE COMPUTING

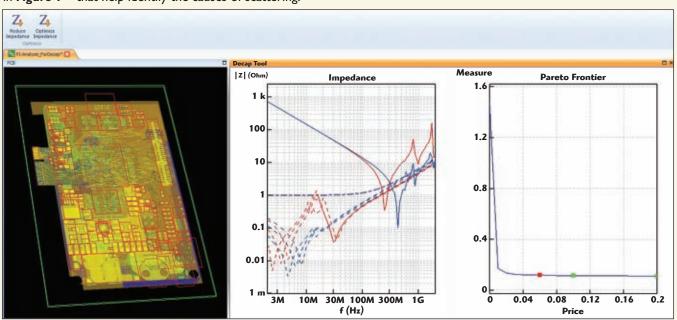
Support for the Intel® Xeon Phi[™] hardware acceleration family and for high-performance cluster storage increases the high performance computing capabilities of the 2015 release.

CST STUDIO SUITE 2015 introduces a range of new features that make synthesis, simulation and optimization of designs more efficient. All of these are built into CST STUDIO SUITE, broadening its capabilities while maintaining the familiar user interface.

VENDORVIEW

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▲ Fig. 2 The decap optimization tool, showing the circuit board (left), impedance curves for several decoupling capacitor configurations (center) and the Pareto frontier (right).

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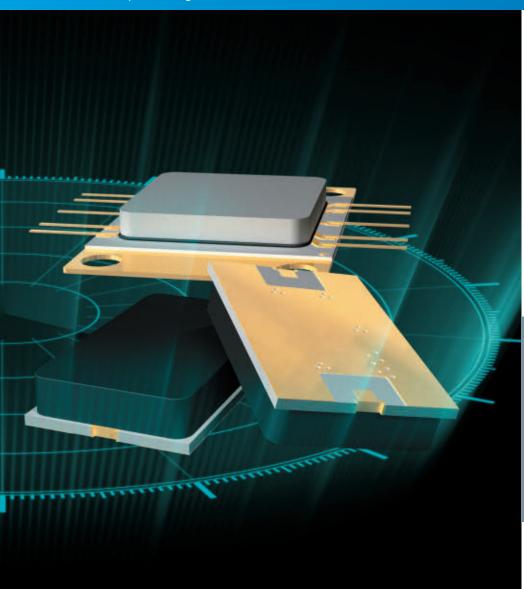
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LM501202-M-C-300	Octave Band, Med Power	500-2000	0.6	30
LM202802-L-C-300	Octave Band, Low Power	2000-8000	1.0	4
LM202802-M-C-300	Octave Band, Med Power	2000-8000	1.2	30
LM401102-Q-C-301	Octave Band, High Power, "Quasi-Active"	400-1000	0.3	100
LM102202-Q-C-301	Octave Band, High Power, "Quasi-Active"	1000-2000	0.5	100
LM202802-Q-C-301	Octave Band, High Power, "Quasi-Active"	2000-8000	1.4	100
LM401402-Q-D-301	Decade Bandwidth, High Power	400-4000	0.75	50

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OCTAVE BA	ND LOW N	OISE AMDI	IEIEDC			
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 1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 IYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	MOISE AND	3.0 MAX, 2.5 TYP MEDIUM POV	+10 MIN	+20 dBm	2.0:1
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 CA910-3110	7.25 - 7.75 9.0 - 10.6	32 25	1.2 MAX, 1.0 TYP	+10 MIN +10 MIN	+20 dBm +20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.4 MAX, 1.2 TYP 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 CA1415-7110	12.2 - 13.25 14.0 - 15.0	28 30	6.0 MAX, 5.5 TYP 5.0 MAX, 4.0 TYP	+33 MIN +30 MIN	+42 dBm +40 dBm	2.0:1 2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1
			TAVE BAND AN		TOT GDIT	2.0.1
Model No.	Freq (GHz)	Gain (dB) MIN		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 CA0108-4112	0.1-8.0 0.1-8.0	26 32	2.2 Max, 1.8 TYP 3.0 MAX, 1.8 TYP	+10 MIN +22 MIN	+20 dBm +32 dBm	2.0:1 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 3.5 MAX, 2.8 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116 CA218-4110	2.0-18.0 2.0-18.0	30 30	5.0 MAX, 3.5 TYP	+10 MIN +20 MIN	+20 dBm +30 dBm	2.0:1 2.0:1
CA218-4110	2.0-18.0	29	5.0 MAX, 3.5 TYP	+20 MIN +24 MIN	+30 dBm	2.0:1
LIMITING A		27	J.0 MAX, J.J 111	TZ 7 7/111V	TOT UDIII	2.0.1
Model No.		nput Dynamic Ro	ange Output Power F		er Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dB		dBm +/	/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dB		8 dBm +/	/- 1.5 MAX /- 1.5 MAX	2.0:1
CLA712-5001 CLA618-1201	7.0 - 12.4 6.0 - 18.0	-21 to +10 dB -50 to +20 dB		7 (IDIII +/	/- 1.5 MAX /- 1.5 MAX	2.0:1 2.0:1
AMPLIFIERS V				7 ubili +/	- I.J MAA	2.0.1
Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB) Pow	er-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			20 dB MIN	2.0:1
CA56-3110A	5.85-6.425 6.0-12.0	28 2 24 2			22 dB MIN 15 dB MIN	1.8:1 1.9:1
CA612-4110A CA1315-4110A	13.75-15.4	25 2			20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0				20 dB MIN	1.85:1
LOW FREQUE			,			
Model No.	Freg (GHz) (Gain (dB) MIN			3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211 CA001-2215	0.04-0.15 0.04-0.15	24 23	3.5 MAX, 2.2 TYP 4.0 MAX, 2.2 TYP	+13 MIN +23 MIN	+23 dBm +33 dBm	2.0:1 2.0:1
CA001-2213	0.01-1.0	28	4.0 MAX, 2.2 TTP	+17 MIN	+33 dBm	2.0:1
CA002-3114	0.01-2.0		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		4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1
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Global Military Radar Market Continues Growth Trajectory

arly warning and surveillance along with fire control radars will account for about 76 percent of the global military radar market between 2013 and 2023, with the total market growing to over \$18.5 billion, according to Strategy Analytics Advanced Defense Systems (ADS) forecasts covering the global military radar market. The forecast includes expenditure and system shipments across land, air, sea and space domains.

North America will continue to represent the largest

"The associated market for semiconductors and other components will grow from \$1.2 to \$2.1 billion with GaN becoming an established technology..."

regional end market, but the fastest growth will be exhibited by demand from the Asia-Pacific region. Airborne radar will represent the largest market, both in dollars and total shipments. L, S and C-Bands will represent the largest market followed by radars operating at X-Band, reflecting the primary frequencies used by surveillance/early warning and fire control radars.

"The total number of radar shipments is forecast to grow at a CAGR of 4.1 percent through 2023, reaching 1393 units," notes Eric Higham, North American director for ADS. "Fire control radar shipments will continue to dominate the traditional mix, but the fastest growth in shipments will come from emerging platforms such as unmanned systems as well as new radar system types".

"The associated market for semiconductors and other components will grow from \$1.2 to \$2.1 billion, with GaN (gallium nitride) becoming an established technology as it grows at a CAGR of 26.4 percent and finds use across all radar systems," added Asif Anwar, ADS director at Strategy Analytics.

Need for High Throughput Connectivity in Defense Drives Global Satcom Applications

he demand for high throughput military satcom (MilSatCom) applications is growing as the use of unmanned aerial systems and implementation of command, control, communications, computers, intelligence, surveillance and reconnaissance of C4ISR systems increase. High throughput satcom applications can support imagery streaming and seamless connectivity across tactical and strategic networks – capabilities which have become vital in the military space.

New analysis from Frost & Sullivan, "Analysis of the

Global Military Satcom Applications Market," finds that the market earned revenues of \$3.05 billion in 2013 and estimates this to reach \$3.82 billion in 2022. The study covers manpack/handheld, ground vehicle, air platform, naval platform mounted and fixed MilSatCom applications.

"To support MilSatCom suppliers and service providers, governments and commercial operators are launching high throughput satellite systems which are driving Ka-Band capacity," said research analyst Arun Kumar Sampathkumar. "Currently, unused satellite spectrum capacity is delaying the migration to high throughput frequencies, hence lowering MilSatCom hardware expenditures. As military users migrate to Ka bandwidth and Internet protocol (IP)-based strategic military communication networks, spending on MilSatCom will rise."

Globally, spending is focused on upstream spectrum procurement. As a result, spending on hardware upgrades will go up in the coming decade and stimulate the use of MilSatCom applications.

With the recent amendment to the United States Defense Authorization Act, which necessitates the adoption of a long-term strategy for commercial spectrum procurement, the market will continue expanding. Hardware manufacturers are planning to offer multi-band satcom

terminals to meet the upgrade trend, while allowing users to operate across existing and upcoming capacities.

However, reducing military budgets and force downsizing, especially among western defense forces – the big spenders in the MilSatCom domain – are dampening the prospects of hardware providers. The withdrawal of troops from Afghanistan, budget sequestration in the U.S. and reduced deployment of special forces

opportunities for
MilSatCom suppliers
will come from the
Middle East and AsiaPacific markets, where
defense spending
and cross-border
security concerns are
increasing..."

have especially restricted MilSatcom spending.

To win contracts globally, MilSatCom suppliers should offer cost-effective solutions that enable defense forces

offer cost-effective solutions that enable defense forces to reduce their overall upstream and downstream expenditure. This will help hardware suppliers secure satellite capacities and promote their new age MilSatCom capabilities as solutions rather than stand-alone hardware offerings.

"Strong opportunities for MilSatCom suppliers will come from the Middle East and Asia-Pacific markets, where defense spending and cross-border security concerns are increasing," pointed out Sampathkumar. "Suppliers must target these markets that have evolving MilSatCom needs not entirely met by proprietary systems."

For More Information

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TRS-3D Naval Radar Provides Information Superiority in Maritime Security



irbus Defense and Space Inc. has installed and put into operation the third TRS-3D naval radar for the U.S. Navy's Littoral Combat Ship (LCS) program through its agreement with the LCS prime contractor Lockheed Martin. The radar has been integrated on the

"The TRS-3D is a three-dimensional, multimode naval radar for surveillance, self-defense, gunfire support and helicopter control. It is used to automatically locate and track all types of air and sea targets."

third "Freedom" variant of the new Littoral Combat Ship, "Milwaukee" (LCS 5). In total, eight TRS-3D radars, designated AN/SPS-75 by the U.S. Navy, have passed their equipment acceptance tests, each now in varying stages of installation within the USS Freedom variant ships.

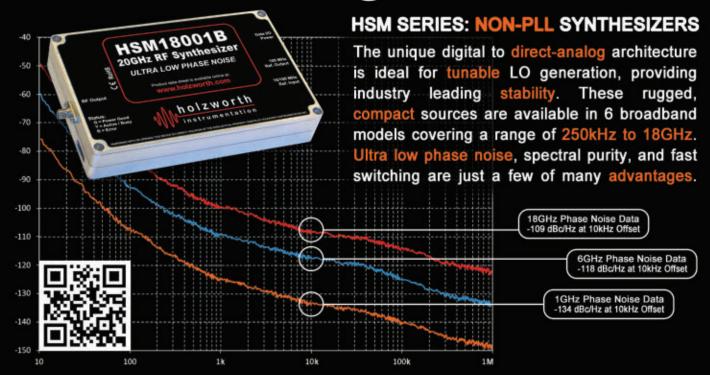
The TRS-3D is a three-dimensional, multimode naval radar for surveillance, self-defense, gunfire support and helicopter control. It is used to automatically locate and track all types of air and sea targets. Among the ships equipped with TRS-3D are the National Security Cutters of the U.S. Coast Guard, and outside the U.S., the K130 corvettes of the German Navy, the "Squadron 2000" patrol boats of the Finnish Navy and the Norwegian Coast Guard "Nordkapp" and "Svalbard" icebreakers.

Littoral combat ships are fast, agile surface combatants optimized for operating in the highly trafficked near-shore regions of the world against asymmetric "anti-access" threats. Through its innovative design, LCS can be reconfigured for surface warfare, anti-submarine warfare and mine countermeasures.



USS Freedom (U.S. Navy photo)

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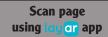














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Richard Mumford, International Editor



Thales and AGH University, Poland Sign Innovation Agreement

nder a new cooperation agreement Thales and one of the leading Polish technical universities – the AGH University of Science and Technology (AGH UST) – will conduct joint scientific research projects for the development and implementation of new technologies. The cooperation will primarily focus on capabilities for space, defence, security and smart transportation.

The main beneficiaries of the agreement are students and graduates of the university as the cooperation will allow practices, internships and assistance in the funding of research projects for students, graduates and university staff.

At the signing ceremony, Pawel Piotrowski, managing director of Thales in Poland, commented, "Thales is investing annually 20 percent of its income in research and development. Thanks to this policy, we are enjoying direct applications of Thales innovations, for example, in the fields of train control solutions. The cooperation between Thales and AGH UST will further boost the capabilities for Polish innovations."

Marko Erman, SVP and chief technical officer of Thales, emphasized, "Over the past years Thales has created an environment that promotes innovation thanks to numerous investments and cooperation with our partners. We are developing common projects with over 50 prestigious universities and research laboratories in Europe, the United States, the Middle East and throughout Asia. Our

"...both parties will gain a lot from this collaboration."

Polish partners are joining a group of international experts thanks to AGH, their scientists and promising talents."

"We often emphasize the strong links AGH has with industry and business – we have almost 300 agreements concerning close cooperation with the largest companies in many industries. But cooperation with Thales, due to its huge potential, has a special meaning for us. I am sure that both parties will gain a lot from this collaboration," said AGH UST vice-rector for cooperation, Prof. Tomasz Szmuc.

RFEL Awarded Follow-On R&D Contract by ESA

FEL has been awarded a follow-on research and development contract by the European Space Agency (ESA), in collaboration with other European partners. The initial contract covered the research phase into a flexible, wideband receiver front-end architecture for next generation broadband and broadcast satellite services. This requirement needed a software-defined, front-end design that could be configured on the fly to meet whatever the

service demands required.

One element that RFEL introduced to the research was the use of a flexible and dynamically reconfigurable, digital filter bank based on its ChannelCore Flex (CCF) design. The CCF design can extract up to 32 independent channels from an instantaneous bandwidth of 2 GHz, which is supplied from a high-speed analogue to digital converter (ADC) running at 5 Gsps. Each output channel can be independently configured at run-time for a bandwidth up to 500 MHz, sample rate of either $2\times$ or $4\times$ bandwidth, centre frequency and output filtering type. The only constraint is that the total bandwidth of all output channels must be no more than 500 MHz. RFEL believes the channeliser

to be one of the most efficient digital architectures available (in terms of silicon resources).

"The research element of the project was a great success," said Alex Kuhrt, RFEL's CEO, "so this "The research element of the project was a great success..."

second, follow-on contract has now been placed by ESA to build a prototype demonstrator that includes the full, front-end receiver chain with all the digital processing demonstrated in FPGA technology."

The funding provided by ESA for this project has resulted in the creation of technology that will be taken forward to assist in the development of the next generation of receiver technology for flexible, wideband satellite receivers.

ETSI and NGMN Cooperate on Future Mobile Broadband Solutions

fter many years of successful collaboration in the areas of LTE, Open Radio equipment Interface (ORI), the Multi-SDO initiative on network management and others, the European Telecommunications Standards Institute (ETSI) and the Next Generation Mobile Networks (NGMN) Alliance have agreed to intensify the joint cooperation beyond the existing Memorandum of Understanding framework.

The new cooperation agreement will provide a thorough framework for future cooperation between ETSI and NGMN. It will improve the dialogue and exchange of information between the two organizations and also provide a mechanism for exchanging draft documents and referencing each organization's specifications. Going forward, ETSI and NGMN plan to work closely on the next generation of mobile networks, in particular to support standardization with a view to upcoming 5G technologies.

Peter Meissner, CEO of NGMN, stated, "The new agreement honours the good and long-standing relationship between ETSI and NGMN and recognizes the importance of both organizations in shaping future mobile broadband solutions."

For More Information

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InternationalReport

Luis Jorge Romero, ETSI director general welcomed the new cooperation agreement, "Cooperation between standards development organizations is required, in particular when dealing with subjects of common interest for the mobile industry, like the development of 5G, in order to avoid conflicting standards and increased cost to the industry. We welcome the strong relationship with NGMN and the extension of our cooperation into new fields."

EU Companies Must Boost R&D Investment to Stay Globally Competitive

nvestment in research and development by companies based in the EU grew by 2.6 percent in 2013, despite the unfavourable economic environment, according to the European Commission's 2014 EU Industrial R&D Investment Scoreboard. However, this growth has slowed in comparison to the previous year's 6.8 percent. It is also below the 2013 world average (4.9 percent) and lags behind companies based in the U.S. (5 percent) and Japan (5.5 percent).

Data collected for the Scoreboard showed that EU-based companies surveyed invested €162.4 billion in 2013, whereas the U.S.-based companies surveyed invested €193.7 billion and the 387 Japanese companies invested

€85.6 billion.

Carlos Moedas, commissioner for research, science and innovation said, "Despite the harsh economic climate, EU companies continue to invest in R&D. That is good news, but more is needed

"Horizon 2020 is already engaging more businesses than ever before..."

to keep up with our competitors. With public resources limited, attracting private R&D investment is even more essential. Horizon 2020 is already engaging more businesses than ever before, but now we're ready to step up our game. The €315 billion investment plan presented by the commission and European Investment Bank will help to raise more private investment for riskier projects, benefiting R&D across Europe."

Tibor Navracsics, commissioner for education, culture, youth and sport highlighted, "Thanks to the presence of excellent researchers and good knowledge-sharing opportunities, Europe is an attractive destination for R&D investment. But to keep up with global competitors we need to boost investments – and these should benefit a range of research disciplines and sectors. Building a knowledgeable economy requires strong foundations and we count on our industry partners to help us in these efforts."



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The molded plastic **YAT** family uses an industry proven, high thermal conductivity case and has excellent electrical performance over the frequency range of DC to 18 GHz, for prices starting at \$2.99 ea. (qty. 20).

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CommercialMarket

Cliff Drubin, Associate Technical Editor



hipments of LTE smartphones supporting more cellular bands will drive antenna tuner shipments to billions of units per year, according to Strategy Analytics:

- More than one billion phones will ship with antenna tuners in 2019, each using two or more antenna tuners on average.
- Benefits will go to top RF front-end subsystem and antenna tuning component suppliers RFMD (Qorvo), Qualcomm, Skyworks and Peregrine (Murata).
- Antenna specialists and smaller suppliers promoting new technologies such as RF MEMS tuners will also win some share.
- OEMs, wireless operators and consumers will benefit with better-performing smartphones.

Antenna tuners have emerged quite recently as an important means of improving call quality mainly in LTE phones, which have less space available for antennas tasked with supporting an ever-increasing number of cellular bands.

According to Christopher Taylor, director of the RF & Wireless Components (RFWC) strategic advisory service

"CMOS SOI switches for configuring the antenna lead the market..."

and author of the report, "CMOS silicon on insulator (SOI) switches for configuring the antenna lead the market, supplied primarily by RFMD, Qualcomm and Skyworks, with a host of other suppliers not far behind. What sets the leading suppliers apart

is expertise in RF switch technology and a breadth of RF front-end products and subsystem solutions."

Steven Entwistle, VP of Strategic Technologies, added, "RF MEMS look very promising as a technology for tunable antennas, adjustable PA impedance and potentially even tunable RF filters. We expect to see antenna tuning design wins for MEMS-based devices from Cavendish Kinetics and WiSpry in phones in 2015 and could see MEMS take a significant share of the market by 2019."

Small Cell Backhaul Market to \$5 Billion by 2019 as mmWave Technologies Advance

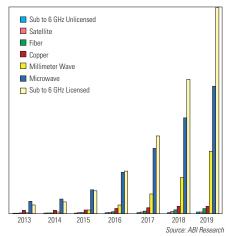
BI Research expects the small cell backhaul equipment market to exceed \$5 billion in 2019, which aligns with operators' deliberate approach to small cell deployments. Millimeter wave technology – thanks to its large bandwidth and NLOS capability – is the fastest growing technology in the forecast, outpacing the overall market with over 100 percent CAGR between 2014 and 2019. Sub 6 GHz technology will capture the largest share of small cell backhaul "last mile" links, also outperforming the total market by 2019. Traditional microwave equip-

ment remains a top technology for small cell backhaul applications, with a leading share of revenue and one-fourth the share of links in 2019.

"We believe that 4G/LTE small cell solutions will again drive most of the microwave, millimeter wave and sub 6 GHz backhaul growth in metropolitan, urban and suburban areas; and backhaul for 4G/LTE small cells will grow at 2× the rate for 3G, surpassing both 2G and 3G in 2016," says Nick Marshall, research director at ABI Research.

"While the North American and Asia-Pacific regions today are equivalent in market share, we forecast that the Asia-Pacific region will outperform the market with 2 to 3× the size of any other region, though North America and Europe will also outperform the market," continues Marshall. Leading vendors such as Alcatel-Lucent, NEC, Ericsson, DragonWave, Ceragon, Aviat, CCS and Siklu are among the vendors which stand to benefit from this growth.

Backhaul Equipment Revenue by Technology World Market Forecast: 2013 to 2019



Device-to-Device Communications, Machine Learning and Cellular RAN Virtualization Top Technology Disruptors

echnology can either be a differentiating factor that helps businesses be successful, or it can be something that contributes to a company's downfall. Technology adoption and usage can help to increase efficiency, increase stickiness, reduce wastage, improve product development, improve service and improve time to market. Technology is at the heart of many business success stories. The role of the CIO is a recent development and becoming one of the key positions within a company, also one of the most challenging.

ABI Research has collected inputs from the ABI analyst community as to what technologies should be on any CIO's or product manager's radar and should be considered when looking at the future roadmap of either products or internal solutions. The top technologies were grouped into the following categories:

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CommercialMarket

Top 5 Overall:

- 1. Device-to-Device Communications (D2D)
- 2. Machine Learning
- 3. Cellular RAN Virtualization
- 4. Bluetooth Low Energy/Bluetooth Smart
- 5. LTE-Advanced

Most Potential Impact:

- 1. Device-to-Device Communications (D2D)
- 2. WiGig
- 3. Energy Storage for Portable Devices
- 4. Graphene
- 5. Machine Learning

Time to Disruption:

- 1. Cellular RAN Virtualization
- 2. ISW and Unified SON
- 3. Bluetooth Low Energy/Bluetooth Smart
- 4. In-Vehicle Smartphone Standards
- 5. Machine Learning

Highest Probability:

- 1. Cellular RAN Virtualization
- 2. Bluetooth Low Energy/Bluetooth Smart
- 3. Machine Learning
- 4. LTE-Advanced
- 5. Device-to-Device Communications (D2D)

LTE Handset Shipments Expected to Soar to Nearly 680 Million in 2015

BI Research estimates that 676 million 4G LTE handsets will be shipped in 2015, growing 204 million from 2014. The total number of LTE connected devices shipped worldwide will exceed 1.89 billion units by end 2019, demonstrating the need for infrastructure and spectrum to support the stellar growth in the industry.

"With the proliferation of larger screen smart devices driving up the insatiable appetites for content and faster speeds, ABI Research estimates that there will be 350 commercial LTE networks by 4Q 2014," comments Cheri Wong, research analysis. LTE-Advanced is now commercial on 20 networks in 14 countries. To cope with the demand for higher data rates, FDD/TDD LTE carrier aggregation trials are starting to take place. Ericsson, Sing-Tel and Qualcomm demonstrated a downlink speed of 260 Mbps in their trial. The first ever TDD-FDD LTE trial took place in February 2014 between Korea Telecom and SK Telecom, with assistance from Nokia Networks. The growing demand for data also emphasizes the need for additional bandwidth to support the massive strain on operator networks which can be alleviated through the re-farming of unused spectrum.



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Around the Circuit

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

M/A-COM Technology Solutions Holdings Inc., a supplier of high performance RF, microwave and millimeter wave products, announced it has successfully completed its previously announced acquistion of **BinOptics Corp.**, a merchant provider of indium phosphide lasers for data centers, mobile backhaul, silicon photonics and access networks, in an all-cash transaction valued at \$230 million.

Murata Electronics North America Inc., a wholly owned subsidiary of Murata Manufacturing Co. Ltd., and Peregrine Semiconductor Corp., founder of RF silicon on insulator (SOI) and pioneer of advanced RF solutions, announced that Murata has acquired all outstanding shares of Peregrine. The cash transaction paid the holders of Peregrine common shares \$12.50 per share.

Crane Aerospace & Electronics, **Power Solutions** will be supplying ELDEC Power Conditioning Modules (PCM) to provide flight critical and reliable power management and conversion for the **Honeywell Flight Control Electronics** (FCE) supplied to COMAC. The FCE is part of the flight control fly-by-wire system that will be utilized on the COMAC C919 family of narrow body aircraft. Flyby-wire systems enable an electronic interface between the cockpit and the aircraft flight control surfaces. Crane's PCM selects the proper source, conditions and supplies uninterruptable power to the FCE.

American Certification Body (ACB) announced a coordinated agreement with ART-FI and EMTREK to market and service the ART-MAN SAR test bench to Chinese mobile and laptop manufacturers. ART-MAN is a new Specific Absorption Rate (SAR) testing solution that uses cutting-edge technologies to make SAR testing more accurate, faster and easier to carry-out for the testing engineers and antenna designers. Mobile manufacturers who have an ART-MAN can launch their products faster, because the SAR testing is completed faster. EMTREK is the third largest testing laboratory in China.

NEW STARTS

TE Connectivity announced the official opening of its TE Wearables Lab in Menlo Park, Calif. Exclusively focused on wearable technologies across consumer, medical, industrial and defense businesses, the lab serves as a collaboration center for TE's team of engineers, scientists and its customers throughout the design process. The lab is currently being used by a number of start-up and middle stage companies from design, manufacturing and integration industries.

ACHIEVEMENTS

Skyworks Solutions Inc. announced that its Board of

Directors has authorized the repurchase of up to \$300 million of the company's common stock from time to time prior to November 11, 2016, on the open market or in privately negotiated transactions, in compliance with applicable securities laws and other legal requirements. This newly authorized stock repurchase program replaces in its entirety the \$250 million stock repurchase program which was approved by the Board of Directors on July 16, 2013, and had \$63.9 million of repurchase authority remaining.

Anritsu Co. announced that it is the market leader in approved test cases for TD-LTE Carrier Aggregation and is the only test company with Global Certification Forum (GCF)-approved TD-LTE test cases in the IMS Voice over LTE (VoLTE)-related technology of aSRVCC. Anritsu's leading position in these work items, as well as the FDD variant of aSRVCC, was confirmed by GCF at the CAG meeting held October 14-15 in Los Angeles. The approved test cases are for Anritsu's ME7834L Protocol Conformance Test (PCT) Platform.

Scientists at **Tech-X Corp.** modeled a complex power-loss mechanism that contributes to inefficiencies in the microwave heating of fusion plasmas. This research helped identify when parasitic slow-wave losses near the reactor edge are likely to occur. Detailed simulations of microwave antenna operation in MIT's Alcator C-Mod fusion experiment were carried out using the VSim software. Such modeling, in addition to augmenting scientific understanding of existing experiments, can be used to explore operation scenarios in future devices. The ITER fusion reactor facility, currently under construction in France, is a multibillion-dollar international project with first experiments scheduled in the 2020s.

RF Techniques celebrated its 25th year anniversary in November. They attribute 25 years of success to a meticulous commitment to core values: a commitment to provide superior quality products and a service commitment to their customers.

Raytheon is awarding 36 Engineering is Elementary® (EiE) scholarships to teachers in disadvantaged, rural or inner city schools across the country. Each teacher will receive \$2,500 towards implementing the innovative EiE curriculum developed by the Museum of Science, Boston. EiE was designed by the Museum's National Center for Technological Literacy® (NCTL) to help elementary school educators and students better understand engineering and technology concepts. The award-winning curriculum has already reached an estimated 71,000 teachers and 6.2 million students.

CONTRACTS

API Technologies Corp. announced that it has received a follow-on order for \$1.3 million to provide microwave modules for the latest generation radar. The customer program, anticipated to continue through 2025, is expected to add an additional \$20 million in revenue. The product features the use of a proprietary Glass Microwave Integrated Circuit (GMIC) fabrication process that offers shorter cycle time

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HFSO745R84-5	745.84	0.5 - 12	+5 @ 35 mA	-147
HFSO776R82-5	776.82	0.5 - 12	+5 @ 35 mA	-146
HFSO800-5	800	0.5 - 12	+5 @ 30 mA	-146
HFSO914R8-5	914.8	0.5 - 12	+5 @ 35 mA	-139
HFSO1000-5	1000	0.5 - 12	+5 @ 35 mA	-141
HFSO1600-5 *	1600	0.5 - 12	+5 @ 100 mA	-137
HFSO2000-5 *	2000	0.5 - 12	+5 @ 100 mA	-137

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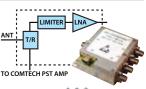


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Around the Circuit

and affordability compared to traditional MMIC-based solutions. GMIC is a medium-volume substrate process where passive components and wire bonds or airbridges are fabricated at wafer level.

Mercury Systems Inc., a provider of affordable, commercially developed, open sensor processing systems and services for critical commercial, defense and intelligence applications, announced that its Mercury Defense Systems subsidiary recently received a \$1.2 million order from a leading international aerospace and defense company for radar environment simulation equipment to support European Fighter Aircraft (EFA). The order was booked in the company's fiscal 2015 second quarter and is expected to be shipped by its fiscal 2016 third quarter.

PEOPLE



Texas Instruments Inc. announced the election of **Robert Furtaw** to vice president of Worldwide Semiconductor (SC) Quality, an organization within TI's Technology and Manufacturing Group (TMG). As vice president, Furtaw will oversee a global team responsible for ensuring TI meets applicable quality requirements and customer expectations, from product and process technology

development through manufacturing and delivery. His team is also accountable for developing and driving the use of methodologies, tools and statistical processes across the company to deliver global, robust products, processes and services.

TriQuint's Glen Riley, vice president of business development, received the prestigious Edward T. Bryand Distinguished Engineering Award from the University



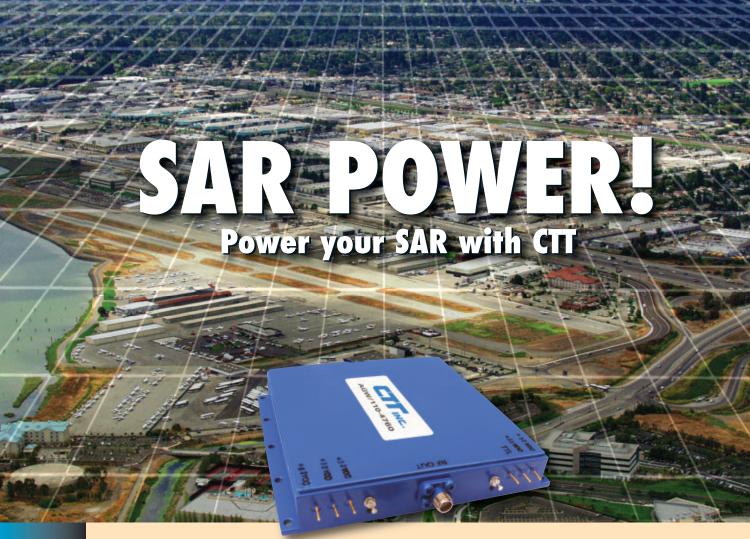
of Maine's College of Engineering. This award is the college's highest honor for career excellence and accomplishment. Riley received the award on November 7, 2014, at the university's annual recognition ban-

quet. Riley joined TriQuint in 2003 and most recently completed a two-year assignment in Singapore as managing director of TriQuint International Pte Ltd. Prior roles at TriQuint include vice president and general manager of foundry services and vice president and general manager of TriQuint Optoelectronics.



▲ Brian O'Leary

Indium Corp. announced that Brian **O'Leary** has joined the company as a global accounts manager. Based in Phoenix, Ariz., O'Leary will be responsible for the management and development of key global accounts. He will work closely with product managers, regional sales managers and technical engineers to develop and execute strate-



The confluence of advances in supporting technologies, such as processors and memories — as well as developments in UAVs — coupled with geopolitical demands for increased homeland security and greater intelligence gathering has pushed SAR (synthetic aperture radar) into the ISR (intelligence, surveillance and reconnaissance) spotlight.

SAR's unique combination of capabilities including all-weather, wide-area and high-resolution imaging is unmatched by other technologies.

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CALL FOR PAPERS

The technical program will cover emerging RF/Microwave technologies, active and passive components and systems as well as wireless communications.

Prospective authors are invited to submit original and high-quality work for presentation at the WAMICON for publication in IEEE Xplore.

Topics of interest include:

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Around the Circuit

gies to maintain existing accounts and grow new business. O'Leary has more than 15 years of experience in global sales across a variety of industries, including electronics assembly and medical device manufacturing.

REP APPOINTMENTS

Modelithics announced an expansion of the partnership with **TACTRON ELEKTRONIK GmbH** in Martinsried, Germany as a reseller for Modelithics library sales and services. TACTRON, currently a reseller for Modelithics in Germany, Switzerland and Austria, will now offer the same excellent reseller representation in Italy and France. For more information, contact Modelithics at sales@modelithics.com or TACTRON at info@tactron.de.

Analog Devices Inc. announced that its complete RF and microwave portfolio, including the Hittite Microwave Products from Analog Devices, is now available for sale through the company's extensive distribution network. ADI's distribution network includes a variety of channel partners worldwide consisting of: global distribution partners; a vast range of regional partners located throughout the Americas, Europe, China and Asia Pacific; and catalog distributors. These partners have been fully trained and received RF and microwave accreditation to ADI standards on the Hittite Microwave products. A complete list of ADI's partners can be found at www.analog.com/salesdir/continent.asp.

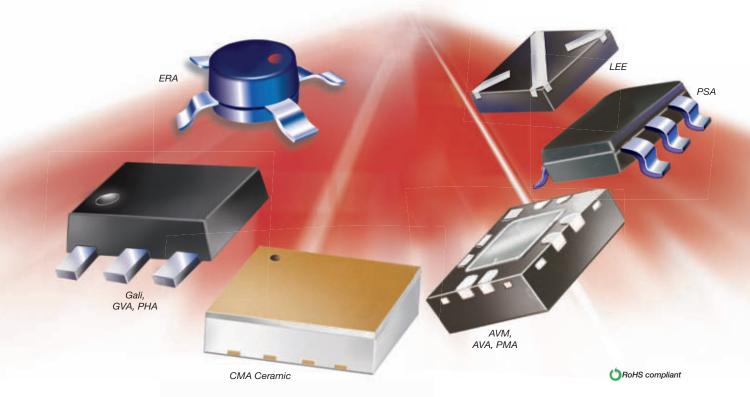
PLACES

Richardson RFPD Inc. announced that it has moved to a larger and newly-renovated office space. The new 24,000-square-foot corporate headquarters is sized to accommodate the company's continued growth as a global leader in the RF and wireless communications, power conversion and renewable energy markets. Richardson RFPD's new offices are conveniently located in historic Geneva, Ill., 40 miles west of Chicago and within 30 minutes of Chicago O'Hare International Airport. The new corporate headquarters is located at 1950 S. Batavia Avenue, Suite 100, Geneva, Ill. 60134. The new main telephone number is 630-262-6800.

Tecdia Inc., a manufacturer of leading edge components and equipment to microwave and lightwave industries has opened a new office branch based in the UK servicing distributors and customers throughout Europe. The office will be managed by their newest addition to the Tecdia Inc. family, Hazel Doughty (former sales manager, Castle Microwave Ltd., UK). Doughty will serve as Tecdia's European sales and distribution manager. Her background covers sales/distribution management and hands-on engineering roles across RF/microwave, smart energy, semiconductors, manufacturing, telecoms and defence related sectors.

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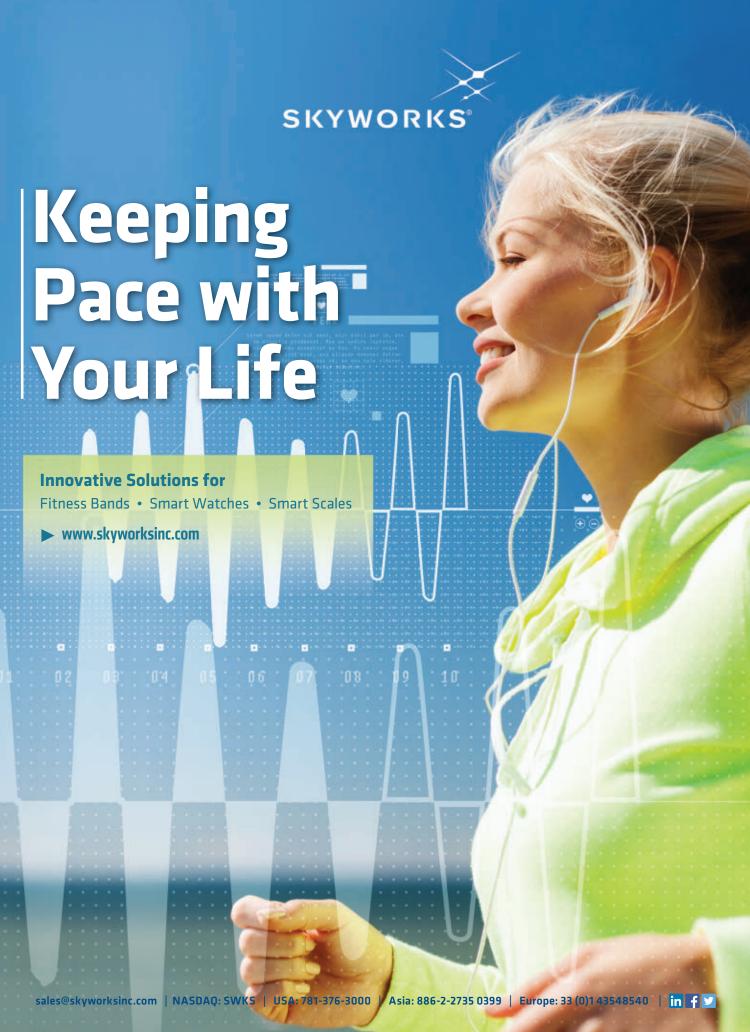
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Metamaterial Möbius Strip Resonators for Tunable Oscillators

Ulrich L. Rohde

Brandenburgische Technische Universitat, Cottbus, Germany

Ajay K. Poddar

Synergy Microwave Corp., Paterson, N.J.

This third article in the series on metamaterial Möbius strip resonators addresses their use in signal sources for test and measurement equipment and wireless communications systems. The resonators enable tunable, multi-band oscillators with smaller size and lower power consumption compared to separate oscillators for each band. The signal sources described in this article demonstrate significant improvements in figure-of-merit (FOM) for a given phase noise, tuning range, power consumption, size and cost. With MMIC fabrication techniques and the broad application of this artificial material, metamaterial technology offers promising planar voltage-controlled oscillator (VCO) solutions for microwave frequencies.

odern communications systems require compact signal sources with low phase noise. For decades, design engineers have been improving phase noise and broadband tuning to satisfy the evolving performance requirements that modern communication systems are demanding. This development has followed two distinct paths: reducing the size of the printed resonator without degrading the quality factor and improving oscillator circuit topologies to improve FOM.

A spot phase noise (PN) number is misleading when comparing oscillators, unless they are at the same frequency offset from the carrier for a given tuning range and output power. To compare oscillators operating at different frequencies, tuning ranges and output power levels, a single number FOM has long been desired. Two metrics being used are a FOM, in dBc/Hz, and power frequency tuning normalized (PFTN), in dB, defined as^{1,28}

 $FOM | f_{offset} =$

$$\left[\mathfrak{L}\left(f_{offset}\right) - 20\log_{10}\!\left(\frac{f_0}{f_{offset}}\right) + 10\log_{10}\!\left(\frac{P_{DC}}{1\text{mW}}\right)\right]\!\!\left(\frac{d\text{Bc}}{\text{Hz}}\right) (1)$$

PFTN =

$$\left[\mathcal{E}\left(f_{offset}\right) - 20\log_{10}\left(\frac{\Delta f}{f_{offset}}\right) - 10\log_{10}\left(\frac{P_{DC}}{kT}\right) \right] (dB) \qquad (2)$$

where f_0 is the oscillation frequency, $\mathfrak{L}(f_{offset})$ is the phase noise at the offset frequency f_{offset} k is the Boltzmann constant, $\Delta f = f_{max}$ - f_{min} or the tuning range, T is temperature in Kelvin, and P_{DC} is the total consumed DC power in mW. The larger the |FOM| and PFTN values, the better the oscillator.

PFTN is a critical requirement for multiband tunable oscillators. The other important requirement is DC to RF conversion efficiency. From equations 1 and 2, the FOM for integrated phase noise, in dBc, from 1 kHz to 1 MHz is given by

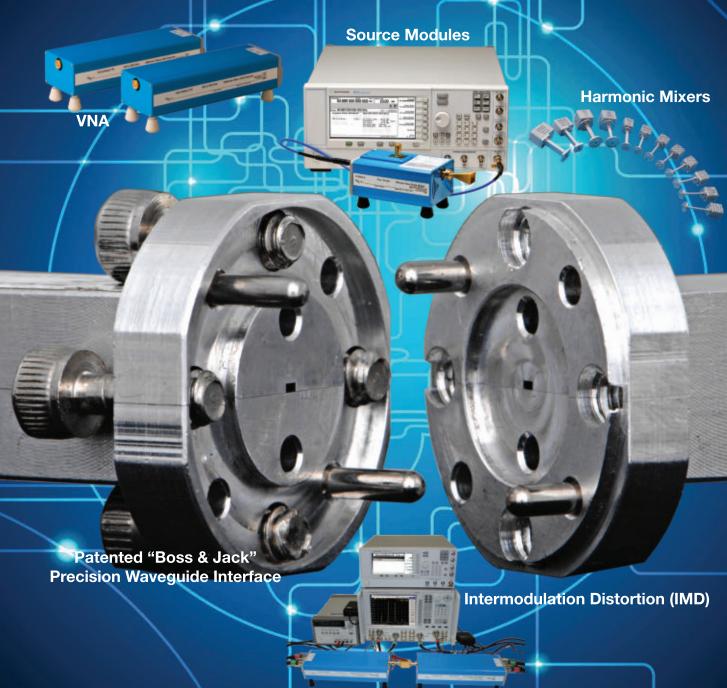
$$FOM \left|_{\text{Integrated}(1kHz-1MHz)} = \right| (3)$$

$$10 log \Big(P^2(\phi)\Big) + 10 log \Bigg(\frac{P_{RF}}{P_{DC}}\Bigg) - 20 log \Bigg(\frac{2\Delta f}{f_{max} + f_{min}}\Bigg)$$

where: $\Delta f = f_{max} - f_{min}$; $f_{max} =$ maximum oscillation frequency; $f_{min} =$ minimum oscillation frequency; $P^2(\phi) =$ integrated phase noise from 1 kHz to 1 MHz; $P_{RF} =$ signal output power averaged over frequency; $P_{DC} =$ DC power consumption of the oscillator.

A compact, high Q-factor resonator is key to obtaining the best FOMs. Toward this goal, substrate integrated waveguides (SIW) are attractive because of their waveguide-like performance and compatibility with planar printed circuit board (PCB) technology.² Cavities





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	COMF	PARISON OF		SLE 1	OR PERFOR	MANCE	
Ref.	f ₀ GHz	P _{DC} mW	P ₀ dBm	Tuning GHz	£(f) dBc/Hz	FOM dBc/Hz	PFTN dB
[6]	25.1	11	-4.2	12%	-99.9	-177	-14.7
[7]	20.9	40	-6.8	10.4%	-111	-181	-11.5
[8]	19.9	39	-3	2.6%	-111	-181	-24.6
[9]	20.7	10.8	-21	8.7%	-108	-181	-24.6
[10]	40	6		2.8%	-109	-193	-14.4
[11]	28	12		6.7%	-113	-191	-6.3
[12]	20.9	6.3		3.1%	-117	-195	-8.5
[13]	18.9	3.3		3.58%	-110	-191	-11.7
[14]	21.3	3.5		5.1%	-109	-190	-8.8
[15]	44	7.5		9.8%	-101	-185	-9
[16]	38.4	80		17.9%	-97.5	-170	-18.3
[17]	17.6	1.4	-9	2.1%	-112	-195	-12.1
[18]	41	280		26.3%	-110	-177	-7.8
[19]	22.1	11.1	-11	20.6%	-109	-181	-2.26
[20]	9.5	37	7.5	4.8%	-117	-180.9	
[21]	11.16	20	2.9	4.1%	-125	-193	
[22]	10	10.5	-2	1.8	-105	-174.8	
[23]	12.4	30	7	2.5	-122	-189.1	
Fig. 7	3.85	300	5	0%	-168	-215	
Fig. 20	10.2	300	10	0.01%	-160	-215	-14.1
Fig. 23	3	100	3.3	66.7%	-130	-179	2.04

based on SIWs are an excellent choice for oscillator resonators, since they have high Os and low loss. Several tunable or switchable SIW resonators have recently been reported.³⁻⁵ Tuning or switching is achieved by connecting a varactor or PIN diode to a floating metal pad on the top of the SIW cavity, using bond wires. However, this creates unwanted radiation loss and reduces the Q, because of the closed-loop slots surrounding the floating metal. Also, the bond wires used for DC bias increase the fabrication complexity and may introduce parasities.

The novel evanescent-mode metamaterial resonator enables the design of oscillators with improved phase noise and FOM compared to other published results. *Table 1* shows the performance of state-of-the-art VCOs that use various fabrication technologies. The metamaterial designs described in this article achieve superior FOM and PFTN for a given class, topology and bill of materials (BOM).

NEGATIVE INDEX PRINTED RESONATOR

The negative index printed resonator is a key component for the design of oscillator circuits at microwave and millimeter wave frequencies. Originally proposed by John Pendry, a typical printed split ring resonator (SRR) is a sub-wavelength resonator that inhibits signal propagation in a narrow band in the vicinity of its resonant frequency, provided the magnetic field is polarized along the axis of the ring. ²⁴⁻²⁶

Recently, a new type of tunable resonator was reported based on complementary coupled resonators (CCR) using SIW technologies.²⁷⁻³³ The proposed CCR is essentially a complementary version of a conventional microstrip coupled-line resonator. *Figure 1a* shows the typical geometry of the conventional coupled-line resonator, *Figure 1b* the equivalent complementary structure. The electric field and current flow of the coupled-line resonator with differential excitation is shown in *Figure 1c*. Using the principle of duality, the

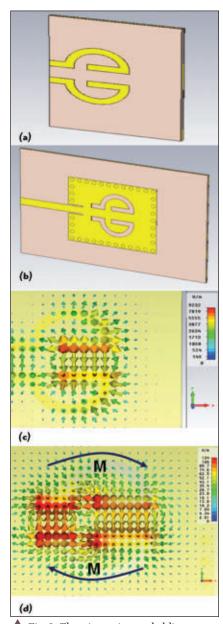


Fig. 1 The microstrip coupled-line resonator (a) and complementary coupled resonator (b). The coupled-line resonator's electric field distribution and electric current flow with differential excitation (c). The magnetic field distribution and equivalent magnetic current flow of the complementary coupled resonator (d). Results from a collaboration between Synergy Microwave and Prof. Tatsuo Itoh of UCLA³³

coupling mechanism for the complementary coupled resonator is through the magnetic field, shown in *Figure 1d*, which has a distribution similar to the electric field in the conventional coupled-line resonator.

In the conventional coupled resonator, the differential mode needs to be excited by a pair of inputs with opposite polarity. However the com-

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plementary coupled resonator is normally excited in a differential mode due to the nature of the fundamental mode in the waveguide. The equivalent magnetic currents on the slots of the complementary coupled resonator flow in opposite directions at the symmetrically opposite edges on the SIW resonator, minimizing radiation and yielding a high Q-factor.

The Q-factors of one and two-port resonators are given by³³

$$\left[Q_{\text{unloaded}}\right]_{1-\text{Port}} = \frac{\omega_0}{2} \left| \frac{Z_{21}(\omega_0)!}{Z_{21}(\omega_0)} \right| \quad (4)$$

$$\left[Q_{\text{loaded}}\right]_{2-\text{Port}} = \frac{\omega_0}{2} \left| \frac{Z_{21}(\omega_0)'}{Z_{21}(\omega_0)} \right| \tag{5}$$

where $Z_{21}\left(\omega_{0}\right)$ and $Z_{21}\left(\omega_{0}\right)$ ' signify the impedance and its derivative, respectively, of the SIW resonator structure at frequency ω_{0} .

The drawback of the CCR structure is its limited tuning range. A pos-

sible way for improving the tuning of the CRR topology is to use negative index material in conjunction with evanescent-mode coupling. Negative index material, broadly known as left-handed (LH), has a negative refractive index.³⁰

$$n = \sqrt{(-\epsilon)(-\mu)} = -\sqrt{\mu_0 \mu_r \epsilon_0 \epsilon_r}$$
 (6)

where n is the refractive index of the medium, ϵ_o = $8.85\times 10^{\text{-}12}$ and μ_0 = $4\pi\times 10^{\text{-}7}.$

The sign of permittivity and permeability in equation 6 is not restricted by any physical law and can be positive or negative. Negative refractive index material has anti-parallel phase and group velocities, which allows an electromagnetic wave to convey energy and group velocity in the opposite direction to its phase velocity. This causes strong localization and enhancement of the fields, significantly enhancing the quality factor of resonators.

In the remainder of this article, several examples of oscillator circuits using Möbius metamaterials are shown. The designs are targeted to replace competing high Q technologies such as surface acoustic wave (SAW), bulk acoustic wave (BAW), surface transverse wave (STW), whisper gallery mode (WGM), ceramic and dielectric resonators.

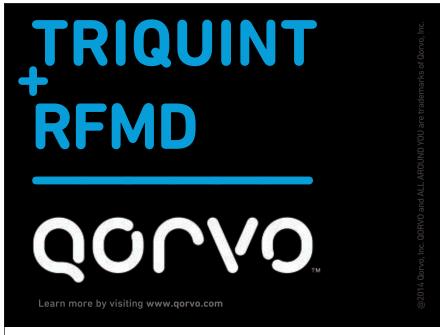
As discussed in the prior two articles (November and December, 2014), the manipulation of evanescent mode coupling enables the Q of the resonator to be multiplied and used for high performance tunable oscillators. The Q multiplier effect does not violate energy conservation because the evanescent mode only stores and does not transport the energy.

Metamaterial Möbius strip resonators have several advantages compared with conventional planar resonators:³⁰

- High Q-factor and improved selectivity
- Easy integration in MIC/MMIC technologies
- Small dimensions and weight
- Multi-band characteristics
- Relative insensitivity to electromagnetic interference

3.85 GHz EVANESCENT-MODE METAMATERIAL MÖBIUS RESONATOR OSCILLATOR

The schematic of a fixed 3.85 GHz oscillator is shown in *Figure 2* and



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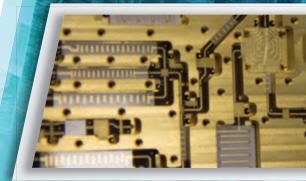
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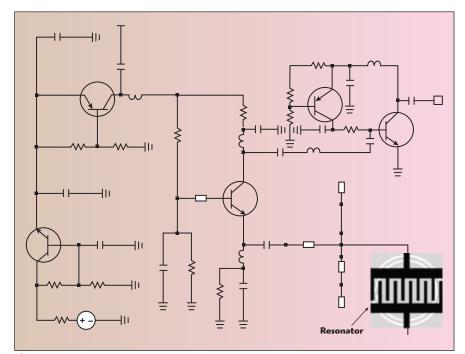


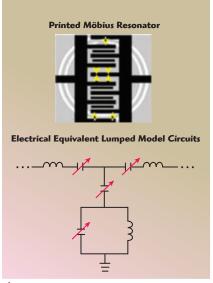
Fig. 2 Schematic of a 3.85 GHz oscillator using an evanescent-mode coupled metamaterial resonator (patent pending)³⁰



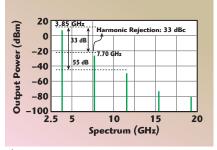
Fig. 3 Layout of the oscillator (patent pending).

the board layout in *Figure 3*. The design uses a SiGe transistor as the active device and a 20 mil thick substrate, with a dielectric constant of 2.2, for the microstrip and stripline matching circuits and interconnects. *Figure 4* provides a close-up view of the metamaterial Möbius strip resonator with varactor diodes that are used for tuning (top); the equivalent circuit of the resonator structure is shown on the bottom.³²

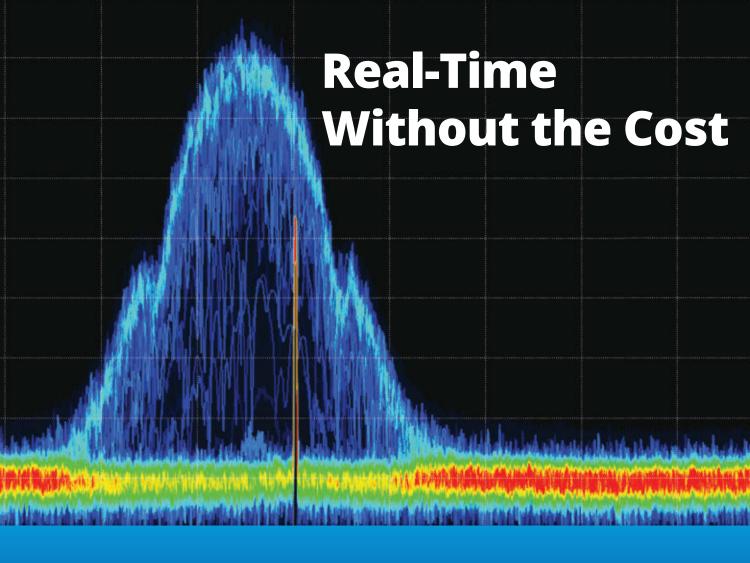
The oscillator is biased at 5 V DC and consumes 60 mA; the measured output power exceeds 5 dBm. *Figure 5* is a plot of the simulated output spectrum, showing that evanescent mode coupling improves the second and third harmonic rejection by more than 33 and 55 dB, respectively. The



▲ Fig. 4 Layout of the metamaterial Möbius resonator with varactor diodes used for tuning (top) with lumped-circuit model (bottom)³⁰



▲ Fig. 5 Simulated spectrum showing the harmonic rejection achieved with evanescent-mode coupling.



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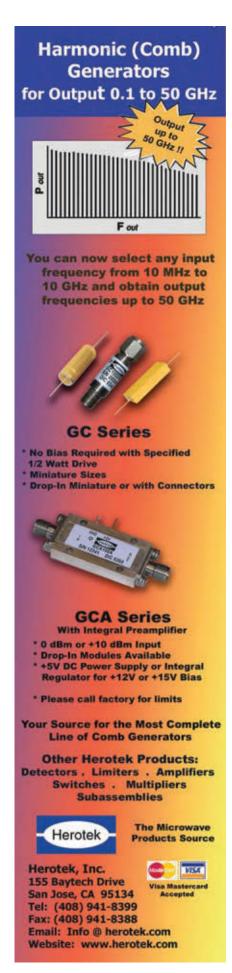
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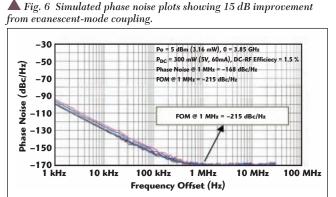
1 KHz

10 KHz

simulated phase noise (see Figure 6) also shows the effect of evanescent-mode coupling, which improves the noise performance by 15 dB. The measured phase noise (see Figure 7) indicates that 5 to 8 dB of the 15 dB predicted improvement is realized, depending upon of the level of evanescent-mode coupling. The FOM for the oscillator is -215 dBc/Hz.

The varactor diodes incorporated in the Möbius resonator improve the tuning, but the oscillator is susceptible to mode jumping, since the resonator structure exhibits both series and parallel resonance. To ensure reliable and stable operation, the

higher order modes are suppressed using a phase-injection locking mechanism.



Frequency Offset (Hz)

Without Evanescent-Mode Coupling -125 dBc/Hz @ 10 kHz

With Evanescent-Mode Coupling -140 dBc/Hz @ 10 kHz

▲ Fig. 7 Measured phase noise of the 3.85 GHz oscillator.

7 GHz EMPIMC RESONATOR BASED OSCILLATOR

The evanescent-mode phase-injection mode-coupled (EMPIMC) oscillator significantly improves phase noise performance, as shown by the simulation in Figure 8. The basic oscillator without phase-injection consists of an analog mixer feeding an LC tank with finite Q-factor and a feedback loop from the output to the mixer, as shown in the block diagram of Figure 9a. To maintain stable oscillation, the loop gain should be greater than unity, and the total phase shift must be zero. The loop gain condition is easily satisfied, but the phase shift condition limits the locking range.²⁴ Considering the phase shift introduced by the LC tank at frequency ω is β , the mixer is required to introduce another phase shift α so that $\alpha + \beta = 0$. By incorporating additional phase shift, γ, after the mixer, the locking range can be increased (see *Figure 9b*).

The locking condition is described by

$$\frac{2(f - f_0)}{f} = \frac{\eta \sin(\phi)}{2 + \cos(\phi)} \tag{7}$$

1 MHz

10 MHz

From equation 7, the locking range is restricted by the maximum phase shift that the mixer can provide and is described by

$$\Delta f = \frac{f_0}{2Q} \tan \left(\sin^{-1} \left(\frac{\eta}{2} \right) \right) \tag{8}$$

where f_0 is the resonant frequency, Q is the quality factor of the LC tank and η is the injection ratio (i_{inj} /IDC). The Q-factor is given by³⁴

$$Q_{L} = \frac{\omega_{0}}{2} \left| \frac{d\varphi(\omega)}{d\omega} \right|_{\omega = \omega_{0}} = \frac{\omega_{0}}{2} \tau_{d}; \tau_{d} = \left| \frac{d\varphi(\omega)}{d\omega} \right|_{\omega = \omega_{0}}$$
(9)

$$\begin{split} \tau_{\rm d} &= \left| \frac{\mathrm{d} \phi(\omega)}{\mathrm{d} \omega} \right|_{\omega = \omega_0} = \\ \frac{\phi(\omega_0 + \Delta \omega) - \phi(\omega_0 - \Delta \omega)}{2\Delta \omega} \end{split} \tag{10}$$

where $\phi(\omega)$ is the phase of the oscillator's open loop transfer function at



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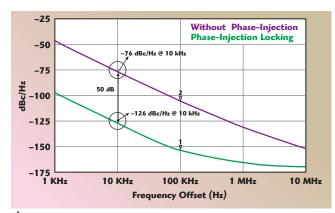


Fig. 8 Simulated phase noise of the evanescent-mode phaseinjection locked oscillator. Phase injection locking improves the noise floor by 50 dB.

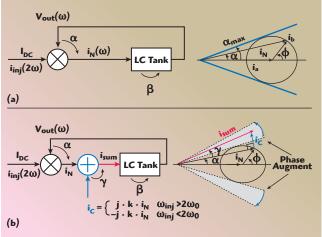


Fig. 9 Oscillator block diagram and phasor diagram for an oscillator without phase-injection (a) and with phase-injection (b).²⁴

steady state, and τ_d is the group delay of the resonator. From equation 9, Q_L is proportional to the group delay; therefore, for low phase noise, the de-

(a) (b) Injection phase: 6 Height: hp Original wave Width : wp Phase shift: Δφ Perturbed wave $= \phi_2 - \phi_1$ (c) ▲ Fig. 10 Oscillator circuit dynamics, showing the limit cycle (a)

 $d\psi/dt$ versus ψ (b) and phase shift due to impulse perturbation at ϕ_i . ²⁴

sign goal is to maxigroup mize the delay of the Möbius strip resonator by incorporating phase-injection techniques. The unique characteristic of the Möbius strip is self phaseinjection along the

mutually-coupled surface of the strips, which enables higher Q-factor for a given size of the printed transmission line resonator.³⁰

By incorporating additional phase shift $\gamma = \tan^{-1} (|i_C|/|i_N)$ after the mixer module, as shown in Figure 9b, the locking range can be increased and is described by 24

$$\begin{split} &\Delta f_{max} = \\ &\frac{f_0}{2Q} \tan \left(\sin^{-1} \left(\frac{\eta}{2} \right) + \tan^{-1} (m) \right), \\ &k = \frac{\left| i_c \right|}{\left| i_N \right|} \end{split} \tag{11}$$

where m is the coupling strength. Figure 10 shows the typical oscillator



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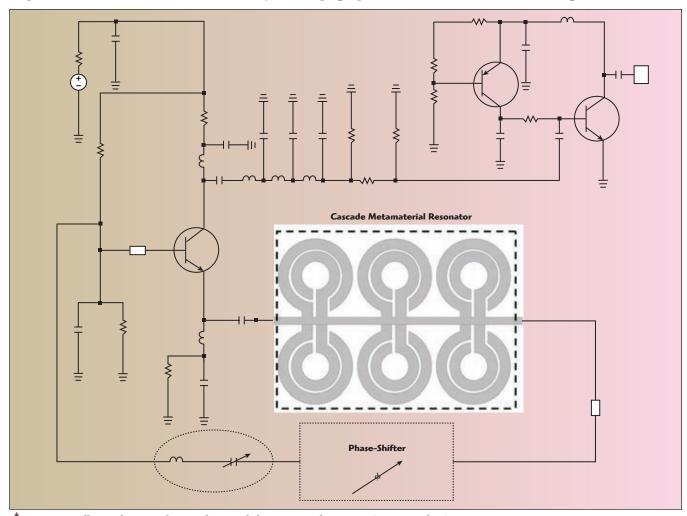
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circuit dynamics for enabling phaseinjection and improving the locking range. An objective of this design was to improve the Q of the metamaterial resonator by cascading a progressive-wave ev-

anescent mode-coupled resonating network (shown in the schematic of *Figure 11*) to lower the phase noise without



▲ Fig. 11 Oscillator schematic, showing the cascaded metamaterial resonator (patent pending).



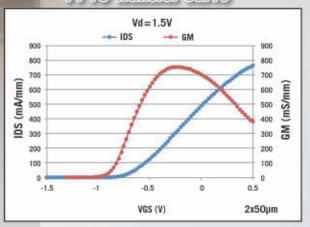




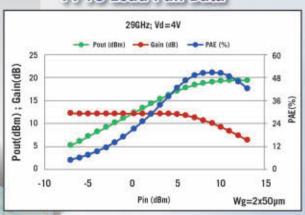
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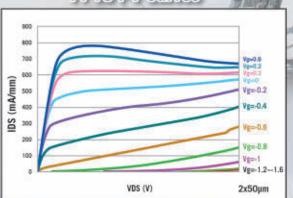
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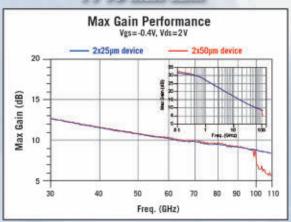
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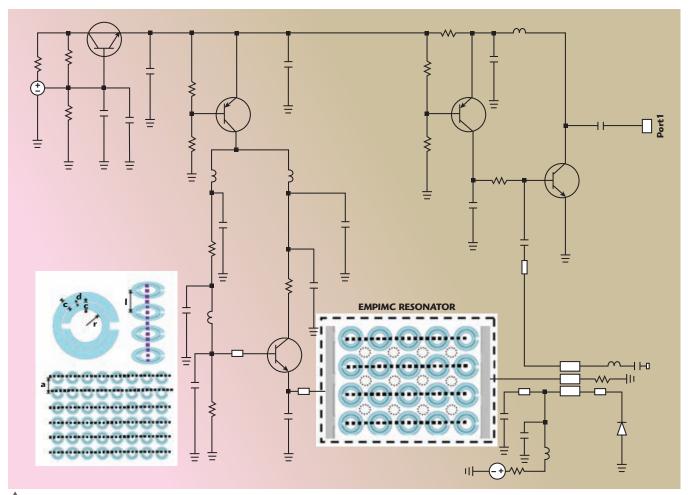


PP10 I-V Curves



PP10 Max Gain





📤 Fig. 12 Schematic of a tunable oscillator using a two-dimensional cascaded injection-locked metamaterial resonator network (patent pending).

compromising the tuning range. Phase-injection locking improves the oscillator's phase noise by 50 dB (see Figure 8). Cascading resonators improves the Q of the overall resonator, because the sharp change in permittivity and permeability at resonance causes a significant increase in the group delay, multiplying the Q. However, one must be careful to avoid or suppress the degeneration modes, which limits the application to below 20 GHz.

The Q-factor of a conventional LC or printed resonator at a given frequency is independent of the current through the resonator, described by

$$Q(\omega) = \frac{\omega_0}{2} \left[\frac{\partial \phi(\omega)}{\partial \omega} \right]_{\omega \to \omega_0}$$
 (12)

where $\phi(\omega)$ is the phase of the resonator impedance.

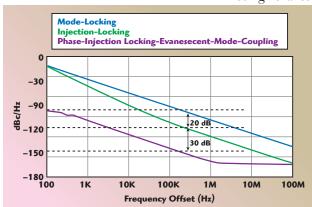
Unlike passive LC resonators, the effective inductance of the metamaterial resonator varies with current and voltage, so this definition of Q is not valid. Accounting for the variation in permit-

tivity and permeability of a metamaterial resonator, the Q is given by³⁰

$$\overline{Q_{a}(\omega)}_{\omega \to \omega_{o}} = (13)$$

$$\left[\frac{\omega}{2(I_{\text{max}} - I_{\text{min}})} \int_{I_{\text{min}}}^{I_{\text{max}}} Q_{a}(\omega, i) di \right]_{\omega \to \omega}$$

where I_{min} and I_{max} are the minimum and maximum currents, and $Q_a(\omega,\!i)$ is the instantaneous quality factor at fre-



▲ Fig. 13 Simulated phase noise of the tuned metamaterial oscillator. Phase-injection locking improves the phase noise by 30 dB.

quency ω and current i. This equation enables the calculation of the Q-factor of a metamaterial resonator when the resonator operates in negative permeability (μ < 0) or negative permittivity (ϵ < 0) conditions.

TUNABLE EMPIMC RESONATOR BASED OSCILLATORS

The schematic of a tunable oscillator using evanescent-mode phase-injec-

tion mode coupling is shown in *Figure 12*. The simulated phase noise is plotted in *Figure 13*. The oscillator covers 4.25 to 5.1 GHz with a tuning voltage from 0 to 12 V (see *Figure 14*) and delivers a typical output power of 3 dBm. The design is biased at 5V and consumes 80 mA. As simulated,





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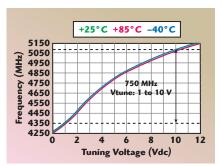
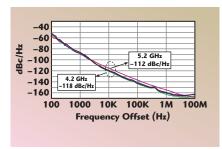


Fig. 14 Tuning characteristics of the oscillator.



▲ Fig. 15 Measured phase noise of the evanescent-mode phase-injection locking oscillator.

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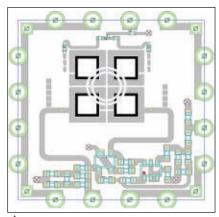
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▲ Fig. 16 Board layout of the X-Band oscillator (patent pending).

evanescent-mode phase-injection locking improves oscillator phase noise by 30 dB compared with injection-locking. The measured phase noise is plotted in *Figure 15*. At 10 kHz offset, the phase noise ranges from -118 dBc/Hz at 4.2 GHz to -112 dBc/Hz at 5.2 GHz.

X-BAND TUNABLE EMPIMC RESONATOR OSCILLATOR

An oscillator using a novel modelocked evanescent-mode metamaterial resonator was developed to provide a tunable signal source for X-Band radar applications. The design uses SiGe HBTs as the active stages and provides 5 dBm output power, drawing 30 mA at 10 V bias. The oscillator is assembled on a 20 mil board with a dielectric constant of 2.2 (see *Figure* 16).

The phase noise of the design, shown in *Figure 17*, exhibits a hump and dip at around 1 MHz offset. This reflects the resonator mode jumping phenomena or, possibly, phase-injection from the measurement equipment. To overcome mode-jumping and tuning problems, mode stabilization is incorporated into the design by introducing a mode-suppression ring that allows multi-mode self-injection into the Möbius strip cavity. A block diagram of the design is shown in Figure 18, with the board layout in Figure 19. Figure 20 plots the measured phase noise of the new design, which has significantly lower phase noise and no hump or dip at 1 MHz offset.

TUNABLE MULTI-BAND OSCILLATORS

The concept of evanescent-mode Möbius metamaterial resonator oscillators can be utilized to make com-

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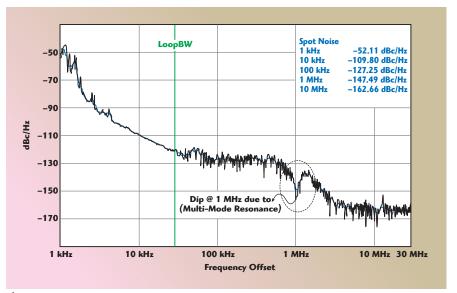
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▲ Fig. 17 Measured phase noise of the X-Band oscillator showing jumping phenomenon at 1 MHz offset.

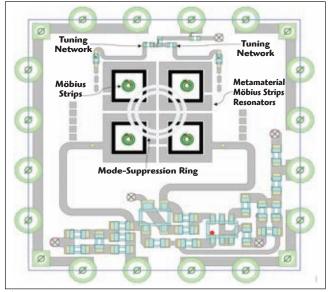
pact, tunable, multiband oscillators that cannot be achieved with conventional printed transmission line resonators. As an example, a tunable oscillator was developed covering four bands: 2 to 2.5, 2.5 to 3, 3 to 3.5 and 3.5 to 4 GHz. It provides a costeffective alternative to traditional VCOs for wireless applications.

A simplified cirschematic is cuit shown in *Figure* Fourth-order, evanescent-mode metamaterial resonators are used to generate the four multi-band frequencies without multipliers or switching among resonators and oscillators. This approach reduces the complexity, size and power consumption of the oscompared cillator, with other methods, performance. The

multiple-band oscillator requires only

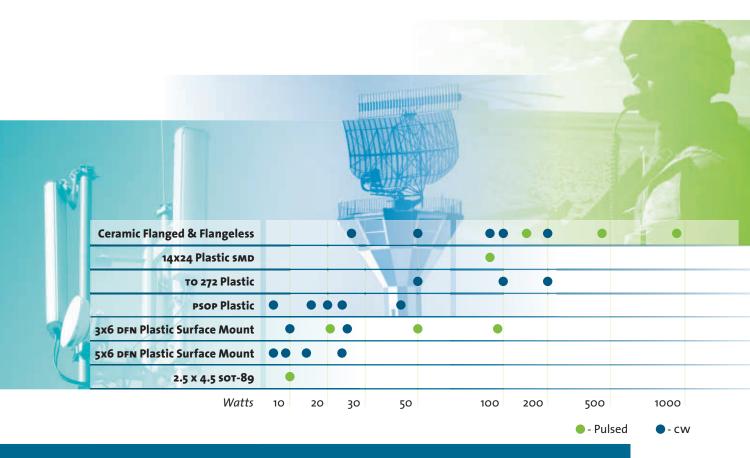
Noise-Feedback DC-Bias Network Injection-Locking Bopt -Möbius-Coupled Collector Tuning-Diode Metamaterial Network Output Split-Ring Resonator Emitter Noise Feedback Phase-Dispersion Minimization Network

▲ Fig. 18 Block diagram of the mode-stabilized oscillator design.



and achieves excel- A Fig. 19 Board layout of the mode-stabilized VCO showing the lent phase-noise Möbius strips and mode suppression ring.

20 mA at 5 V bias and delivers 3 dBm typical output power. The simulated



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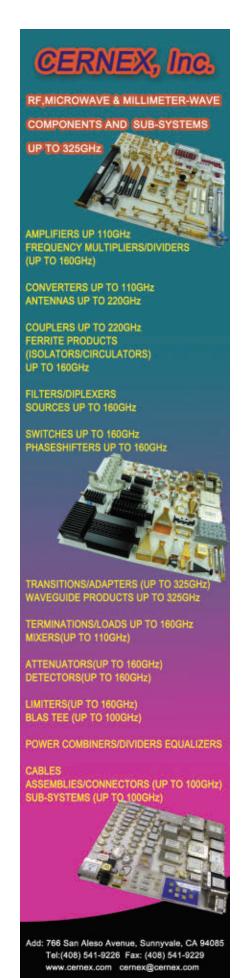
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phase noise is better than -130 dBc/Hz at 1 MHz offset for any of the four bands, as shown in *Figure 22*. The measured phase noise (see *Figure 23*) agrees with the simulations within 3 to 5 dB.

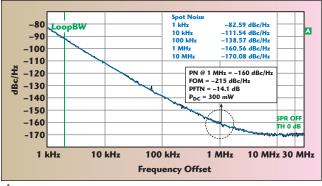
CONCLUSION

Möbius metamaterial technology is a promising alternative to high frequency planar VCO solutions for radio communication systems, enabled

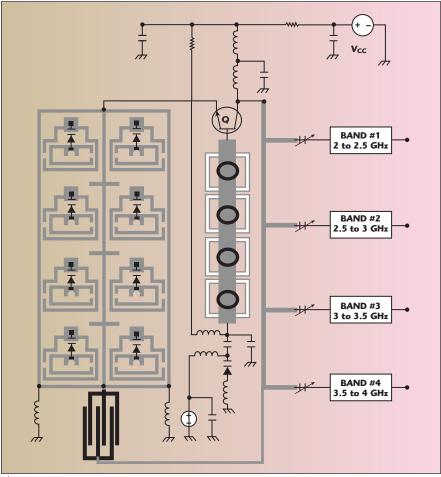
by the development of MMIC fabrication techniques and the broad application of this artificial material. As shown in Table 1, the VCO designs presented in this article show superior FOM and PFTN performance for a given class, topology and BOM.

As stated throughout this se-

ries, the Möbius strip has captured the imaginations of mathematicians and engineers since it was discovered. Its non-orientability and one-sidedness continue to intrigue. Even as applications like conveyor belts with twice the lifespan of non-twisted belts fade out of use, new applications of the Möbius strip, such as the Möbius resistor, are discovered. The Möbius strip will continue to appear, both as a novelty mathematical figure and an



stated Fig. 20 Measured phase noise of the X-Band oscillator after mode stabilizing the design. The noise floor has been significantly improved, with no jumping at 1 MHz offset.



▲ Fig. 21 Simplified schematic of a tunable multi-band oscillator design using an evanescentmode metamaterial resonator network (patent pending).



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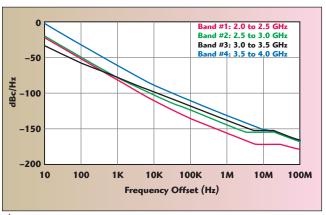
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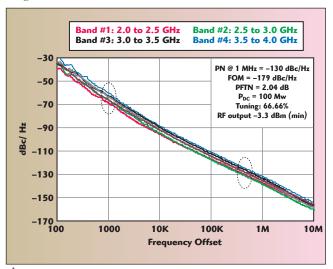
essential component in inventions, recurring in an endless – one could even say Möbius – loop. ■

References

- D. Hamand and A. Hajimiri, "Concepts and Methods in Optimization of Integrated LC VCOs," IEEE Journal of Solid-State Circuits, Vol. 36, No. 6, pp. 896–909, June 2001.
- F. Xu and K. Wu, "Guided-Wave and Leakage Characteristics of Substrate Integrated Wave-guide," IEEE Transactions Microwave Theory & Techniques, Vol. 53, No. 1, pp. 66–73, January 2005.
- 3. Y. Dong and T. Itoh, "A Dual-Band Oscillator with Reconfigurable Cavity-Backed Complementary Split-Ring Resonator," *IEEE MTT-S International Digest*, June 17–22, 2012, pp. 1–3.
- 4. F. F. He, K. Wu, W. Hong, L. Ha and X. Chen, "A Low Phase-Noise VCO Using an Electronically Tunable Substrate Integrated
 - Waveguide Resonator," *IEEE Transactions Microwave Theory & Techniques*, Vol. 58, No. 12, pp. 3452–3458, December 2010.
- S. Sirci, J. D. Martinez, M. Taroncher and V. E. Boria, "Varactor Loaded Continuously Tunable SIW Resonator for Reconfigurable Filter Design," *Proceedings 41st European Microwave Conference*, 2011, pp. 436–439.
- D. Ozis, N. M. Neihart and D. J. Allstot, "Differential VCO and Passive Frequency Doubler in 0.18 mm CMOS for 24 GHz Applications," IEEE RF IC Symposium Digest, 2006.
- S. Ko, J. G. Kim, T. Song, E. Yoom and S. Hong, "20 GHz Integrated CMOS Frequency Sources with a Quadrature VCO Using Transformers," *IEEE RF IC Symposium Digest*, 2004.
- H.H. Hsieh and L.H. Lu, "A Low-Phase-Noise K-Band CMOS VCO," IEEE MWCL, Vol. 16, No. 10, pp. 552–554, October 2006.
- C. M. Yang, H. L. Kao, Y. C. Chang and M. T. Chen, "A Low Phase Noise 20 GHz Voltage Control Oscillator Using 0.18 µm CMOS Technology," *IEEE DDECS*, pp. 185–188, 2010.
- 10. Chien et. al., "40 GHz Wide-Locking-Range Regenerative Frequency Divider



▲ Fig. 22 Simulated phase noise of the multi-band VCO design, designed to cover 2 to 4 GHz.



▲ Fig. 23 Measured phase noise of the multi-band VCO design covering 2 to 4 GHz.

- and Low-Phase-Noise Balanced VCO in 0.18 µm CMOS," *IEEE International SSC Conference Technical Digest*, February 2007, pp. 544–545.
- 11. Y. Wachi, T. Nagasaku and H. Kondoh, "A 28 GHz Low-Phase-Noise CMOS VCO Using an Amplitude Redistribution Technique," *IEEE International SSCF Tech. Digest*, February 2008, pp. 482–483.
- H.Y. Chang and Y.T. Chiu, "K-Band CMOS Differential and Quadrature Voltage-Controlled Oscillators for Low-Phase-Noise and Low-Power Applications," *IEEE Transactions Microwave Theory Techniques*, Vol. 60, No. 1, pp. 46–59, January 2012.
- T.P. Wang, "A K-Band Low-Power Colpitts VCO with Voltage-to-Current Positive-Feedback Network in 0.18 µm CMOS," IEEE MWCL, Vol. 21, No. 4, pp. 218–220, April 2011.
- Lîu et al., "A Low-Power-Band CMOS VCO with Four-Coil Transformer Feedback," *IEEE MWC*, Vol. 20, pp. 459–461, 2010.
- 15. J. Kim et al., "A 44 GHz Differentially Tuned VCO With 4 GHz Tuning Range in 0.12 m SOI CMOS," *IEEE International* Solid-State Circuits Conference Digest, February 2005, pp. 416–417.

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- O. Richard et al., "A 17.5 to 20.94 GHz and 35 to 41.88 GHz PLL in 65 nm CMOS for Wireless HD Applications," *IEEE Interna*tional SSC Conference Digest, February 2010, pp. 252–253.
- S. Choi, Y. Jeong and K. Yang, "Low DC-Power Ku-Band Differential VCO Based on an RTD/HBT MMIC Technology," *IEEE MWCL*, Vol. 15, No. 11, pp. 742–744, November 2005.
- H. Li et al., "47 GHz VCO with Low Phase Noise Fabricated in a SiGe Bipolar Production Technology," *IEEE MWCL*, Vol. 12, No. 3, pp. 79–81, March 2002.
- T. Nakamura et al., "A 11.1-V Regulator-Stabilized 21.4-GHz VCO and a 11.5% Frequency-Range Dynamic Divider for K-Band Wireless Communication," *IEEE Transactions on MTT*, Vol. 60, No. 9, pp. 2823–2832, September 2012.
- F. F. He, K. Wu, W. Hong, L. Han and X. Chen, "A Low Phase-Noise VCO Using an Electronically Tunable Substrate Integrated Waveguide Resonator," *IEEE Transactions Microwave Theory Techniques*, Vol. 58, No. 12, pp. 3452–3458, December 2010.
- 21. Z. Chen, W. Hong, J. Chen and J. Zhou, "Design of High-Q Tunable SIW Resona-
- tor and its Application to Low Phase Noise VCO," *IEEE Microwave Wireless Components Letter*, Vol. 23, No. 1, pp. 43–45, January 2013.
- F. Giuppi, A. Georgiadis, A. Collado, M. Bozzi and L. Perregrini, "Tunable SIW Cavity Backed Active Antenna Oscillator," *Electronic Letter*, Vol. 46, No. 15, pp. 1053–1055, July 22, 2010.
- A. Collado, F. Mira and A. Georgiadis, "Mechanically Tunable Substrate Integrated Waveguide (SIW) Cavity Based Oscillator," *IEEE Microwave Wireless Component Letter*, Vol. 23, No. 9, pp. 489–491, September 2013.
- H. Wang et. al., "A 60 GHz Wideband Injection-Locked Frequency Divider with Adaptive-Phase-Enhancing Technique," 2011 RFICS, pp. 75–78.
- Li Zhang, U. L. Rohde, A. K. Poddar and A. S. Daryoush, "Evanescent-Mode Self-Injection Phase-Locked (EMSIPL) OEO," *IEEE IMaRC Delhi*, December 14–16, 2013
- 26. U. L. Rohde and A. K. Poddar, "A Novel Evanescent-Mode Mobius-Coupled Resonator Oscillators," *IEEE Joint UFFC Symposia with European Frequency and Time Forum (EFTF) and Piezo Response Force Microscopy*, July 21–25, 2013.
- U. L. Rohde, A. K. Poddar and D. Sundararjan "Printed Resonators: Möbius Strips Theory and Applications," *Microwave Journal*, November 2013.
- A. K. Poddar and U. L. Rohde, "Latest Technology, Technological Challenges, and Market Trends for Frequency Generating and Timing Devices," *IEEE Microwave Magazine*, pp.120–134, October 2012.
- A. K. Poddar, U. L. Rohde and Anisha Apte, "How Low Can They Go, Oscillator Phase Noise Model, Theoretical, Experimental Validation and Phase Noise Measurements," *IEEE Microwave Magazine*, Vol. 14, No. 6, pp. 50–72, September/October 2013.
- A. K. Poddar, "Slow Wave Resonator Based Tunable Multi-Band Multi-Mode Injection-Locked Oscillators," Dr.-Inh.-habil Thesis, BTU Cottbus, Germany, 2014.
- A. K. Poddar and U. L. Rohde, "Slow-Wave Evanescent-Mode Coupled Resonator Oscillator," 2012 IEEE FCS, pp. 1–7, May 2012.
- 32. A. K. Poddar. U. L. Rohde, "Evanescent-Mode Phase-Injection Mode-Coupled (EMPIMC) Metamaterial Resonator Based Tunable Signal Sources," *IEEE* Wamicon, June 6, 2014.
- 33. C. T. M. Wu, A. K. Poddar, U. L. Rohde and T. Itoh, "A C-Band Tunable Oscillator Based on Complementary Coupled Resonator Using Substrate Integrated Waveguide Cavity," submitted to European Microwave Symposium 2014.
- 34. A. K. Poddar, "Slow Wave Resonator Based Tunable Multi-Band Multi-Mode Injection-Locked Oscillators," research report submitted to the faculty of mechanical, electrical and industrial engineering of the Brandenburgische Technische Universität, Cottbus-Senftenberg, Germany, January 2013, https://www-docs.tu-cottbus.de/mikrowellentechnik/public/ajay/poddar_report_long_ebook.pdf.







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Real Time Radar Target Generation

Steffen Heuel and Darren McCarthy Rohde & Schwarz, Munich, Germany

Radar systems are used across many industries and in a variety of commercial, industrial and defense applications. Uses range from commercial applications such as automotive collision avoidance, weather and air traffic control (ATC) to defense systems such as early warning and missile tracking. The radar's application dictates its physical size, operating frequency, waveform, transmit power, antenna aperture and many other parameters. Every parameter and component must be tested to ensure proper operation.

Radar system operators are interested in functionality testing, namely target detection and tracking. To ensure the accuracy and resolution, detection and false alarm rate of the radar, targets must be generated over the entire unambiguous range, the unambiguous radial velocity interval, azimuth and elevation angles and different radar cross sections (RCS). Testing in the field can be extremely time-consuming, complex and expensive. Repeatable conditions are difficult to configure. For example, consider a radar on a fighter jet that is tested at a test range, where artificial targets are deployed, detected and tracked. The global positioning system (GPS) coordinates of the targets are compared with the collected radar data to verify radar performance.

Since the cost of field-testing can be prohibitive if done on a regular basis, an alternative is to set up "real-life" radar simulations that include many different types of targets and scenarios. Generating radar targets makes it possible to test the functionality of the radar, including RF, without the expense of field testing. Radar target generators can introduce targets with time delay, Doppler frequency shift

and attenuation. Several implementations of target generators have been used, including coaxial delay lines (CDL), fiber optical delay lines (FODL) and digital radio frequency memory (DRFM). Commercial off-the-shelf (COTS) measuring equipment is increasingly used.

The performance and capability of radar target generators to test a radar system depend on several technical parameters. This article explains the different target generator architectures, clarifies the performance needs and design criteria that favor one approach over another and shows examples of measurement results with a COTS system.

RADAR TESTS - LAB OR FIELD?

Many measurements must be performed before a radar system is put into service. During research and development (R&D), mainly hardware component tests are performed. Most of these focus on the transmitter and receiver, with less emphasis on the signal processing and system functionality. As a result, the radar is only partially tested during R&D and important functionality, such as signal detection, is never completely tested in closed-loop operation. To evaluate the complete system (RF and baseband) and ensure that all elements meet specifications and customer requirements, many additional tests are required, as shown in *Figure 1*.

Parametric measurements must be supplemented by tests to evaluate the functionality of the system. Built-in test equipment (BITE) monitors some hardware components and functionalities. While BITE is able to provide a pass-fail assessment, it is not necessarily designed to give information on the radar's per-

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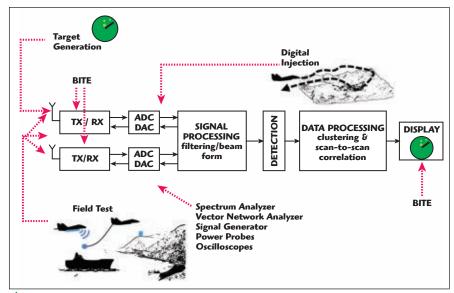


Fig. 1 Extensive tests are performed on a multipurpose radar system.

formance. If a radar does not detect a target, for example, how does the operator know that the radar is not functioning properly?

To address this, field tests with towed spheres may be conducted to baseline radar capabilities and evaluate the entire radar processing chain. However, field tests won't specifically test the processing capabilities. So some radars have a digital injection capability, where scenarios can be loaded into the radar processor to test the processor.

As previously mentioned, field tests are expensive and barely reproducible, and the availability of certain targets is limited. For these reasons, radar target

generators are used to replace some field tests and make tests reproducible; they save time and reduce cost and can test the entire processing chain by injecting targets. The technical demands placed on radar target generators represent a challenge to the fundamental architecture of the target generation system. While economic advantages tend to favor a laboratory test system instead of field testing, the functional performance of the radar system must be verified through a balance of laboratory and field test environments. Furthermore, as radar systems add electronic protection functionality, these new system capabilities may require new test methods.

The test and measurement (T&M) industry offers various types of radar test equipment that can be used during development and production. These focus on the parametric performance of the radar and can measure spectral purity, transmit power and sensitivity.

RADAR TARGET GENERATORS

Radar target generators apply time delay (range), Doppler frequency shift (radial velocity) and attenuation to a radar signal. The actual radar signal is received, manipulated and retransmitted. Other systems have the radar waveform stored and trigger waveform replay. The architecture of radar target generators determines the performance and capability to test different levels of functionality. Some are able to generate a single target in a dedicated frequency band, for very specific radar systems, while others cover a wide frequency spectrum and offer complex target scenario simulation. There are also specific radar target generators for dedicated frequency bands, such as for testing automotive radar sensors.¹

The performance and capability of radar target generators and their ability to test a radar system depend on several economic and technical parameters. Aside from efficiency and cost, the following technical parameters are important:

- System architecture
- Frequency coverage and bandwidth

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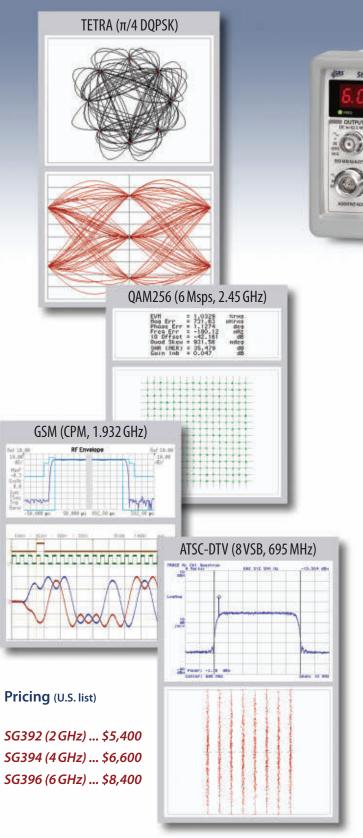
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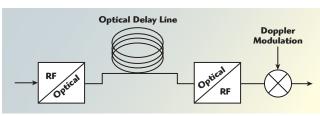
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- Phase noise performance, signal distortion, spurious emissions and overall echo signal quality
- Digitization performance, sampling frequency and number of effective quantization bits
- Maximum Doppler frequency shift and Doppler steps
- Maximum range, minimum range and range steps
- Trigger and/or continuous operation

 Flexibility to reproduce authentic environmental scenarios and possible tests of interest.

Operating frequencies of radar systems vary over a

wide range of bands: Long range surveillance radars operate in high frequency (HF) or L-Band, ATC radars in



igtriangle Fig. 2 Simplified block diagram of a fiber optical delay line (FODL).

S-Band, naval surveillance radars in X-Band and automotive radar sensors in K- and W-Band. Therefore, the radar target generator should cover a broad spectrum. The bandwidth of the target generator must faithfully reproduce the radar waveform, as bandwidth determines the range resolution and the span of frequency agile radars.

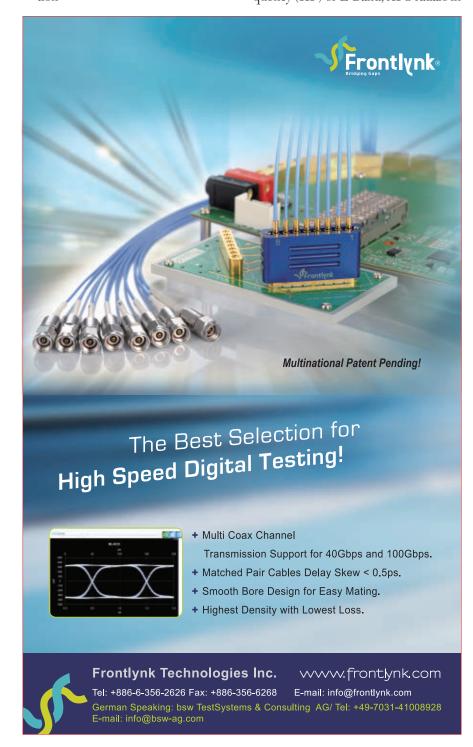
Signal fidelity and phase noise are also important. Poor signal fidelity distorts the retransmitted signal. The radar can only detect slow moving targets if it has low phase noise performance; if the target generator has high additive phase noise, it may limit the ability to assess the actual performance of the radar.

To simulate delay and Doppler, digitization is used in most modern radar target generators. The radar signal is captured, digitized, manipulated, converted to analog and retransmitted with attenuation. The effective number of bits (ENOB) and spurious-free dynamic range (SFDR) quantify the quality of an analog-to-digital converter (ADC) and are important parameters for accurately representing the incoming radar signal and reproducing the radar echo. Other parameters, such as the minimum and maximum range, the number of targets or test scenarios, mainly depend on the signal processing performance, architecture and baseband processing capabilities of the radar target generator.

Today, radar engineers use the following types of radar target generators:

Fiber Optic Delay Lines (FODL)

FODLs have been used for several decades to test radar systems, measuring phase noise and simulating reproducible signals for outdoor range testing. These small, relatively flexible, and phase-coherent systems convert the RF signal to optical, delay it with a fiber optic line of a defined length, reconvert it to RF and retransmit it to the radar (see *Figure 2*). Some systems are able to introduce Doppler frequency shift.





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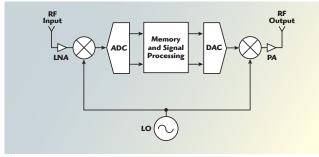


Fig. 3 Simplified block diagram of a DRFM system.

The phase velocity of an optical signal in fiber is approximately 5 µs/km, and the loss is on the order of 0.5 dB/km. Hence, the FODL achieve very good range spacings, i.e., in the domain of picoseconds, when

cut properly. The bandwidth of a FODL is very high. With multimode fibers, bandwidth is mainly limited by the modal dispersion, which is in the range of GHz/km. In single-mode fibers, modulation bandwidth is limited by material dispersion and can be 100 GHz/km for a wavelength with very low dispersion.² Dynamic range is limited by quantum noise at low RF and by nonlinear processes at high RF,3 decreasing linearly with increasing signal bandwidth.2 With a Doppler shift added, the spurious-free dynamic range depends on additional factors and is often reduced by dozens of dB. Although the Doppler frequency shift can modulate the RF signal, the length of the fiber delay (i.e., the range) is constant, and a realistic moving target cannot be generated.

FODLs have several advantages. They have constant delay versus frequency, are immune to vibration and largely resistant to electromagnetic interference, and fiber does not radiate energy. Repeatability of simulation, low system cost and time-savings are also advantages. Where excellent close-in carrier phase noise performance is necessary, such as the fixed target suppression test, FODLs perform very well. However, they cannot generate time-variant range-Doppler targets, nor do they offer continuous range settings or arbitrary signal attenuation and gain.

Digital Radio Frequency Memory (DRFM)

DRFMs manipulate the radar signal digitally, as shown in *Figure 3*. A DRFM down converts, filters and digitizes the received RF signal. The digital data is stored and/or modified, then reconverted to analog and upconverted to RF using the same local oscillator (LO) used for down conversion. Amplification and retransmission of the RF finalizes the processing chain.

The ALQ-165 airborne self-protection jammer (ASPJ) was one of the first DRFMs designed, with development beginning in 1979.⁴ ASPJ initially covered 0.7 to 18 GHz and later, from 1 to 35 GHz. The average cost was \$1.27 million.⁵

Technical performance specifications and the cost of a DRFM are rarely available publicly. From what information is available, the cost of a



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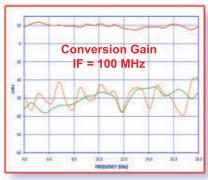
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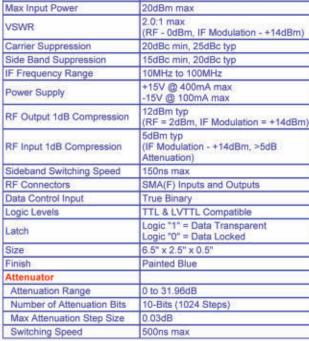
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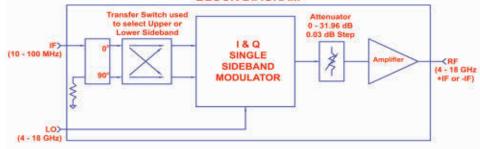
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Frequency Range	4.0 to 18.0GHz	
Conversion Gain	10dB, ±3dB max (RF+ 0dBm, IF Modulation = +14dBm)	12 (2043-MISSON) Hole (\$1027) (214
Max Input Power	20dBm max	₩ Aglent
VSWR	2.0:1 max (RF - 0dBm, IF Modulation - +14dBm)	Annu Lime
Carrier Suppression	20dBc min, 25dBc typ	X 10 (0)
Side Band Suppression	15dBc min, 20dBc typ	
IF Frequency Range	10MHz to 100MHz	THE STATE OF THE S
Power Supply	+15V @ 400mA max -15V @ 100mA max	
RF Output 1dB Compression	12dBm typ (RF = 2dBm, IF Modulation = +14dBm)	
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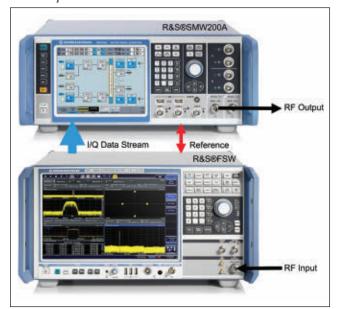
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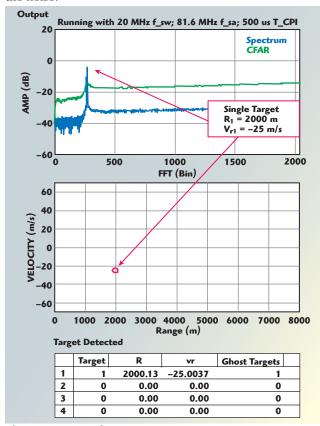
single DRFM module ranges from \$150 to \$700 thousand, depending on capabilities. DRFMs can cover up to 40 GHz, offer 12-bit digitization with 1.4 GHz instantaneous bandwidth, -65 dBc SFDR and a minimum delay of 90 ns. Due to technical restrictions, however, these figures cannot be combined into a single DRFM. For example, most of the wideband DRFMs have lower signal fidelity and use less than 12 bits.

The minimum delay is primarily limited by the ADC and DAC, which take several cycles to convert the analog data to digital and vice versa. The delay also depends on the bandwidth and number of bits. Signal processing adds a number of processing cycles to the radar echo signal. Typical minimum delays now range from below 100 ns to below 1 μs .



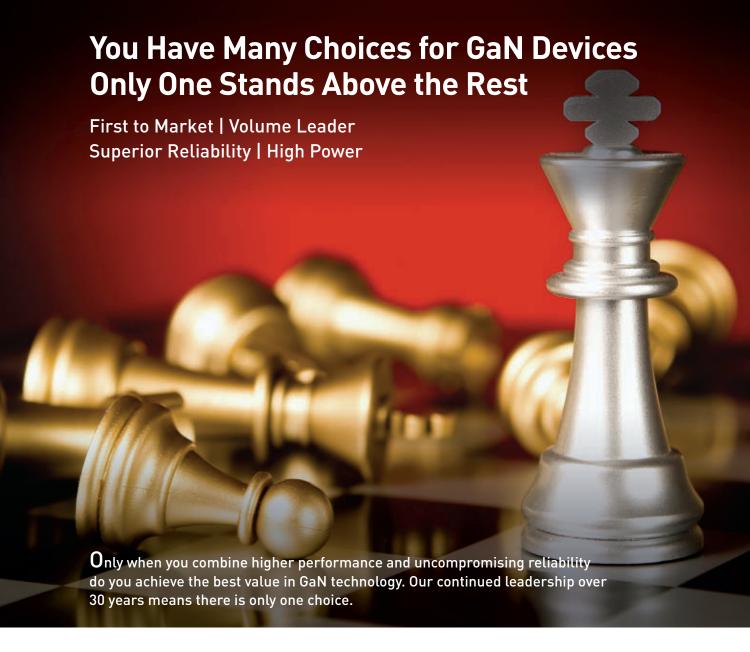
▲ Fig. 4 Example of a COTS radar target generator using the R&S®SMW200A vector signal generator and R&S®FSW signal and spectrum analyzer.

With DRFMs it is important to know how the analog RF signal is represented in the digital domain: the number of bits, amplitude and phase. These determine the signal fidelity. Another key parameter is the SFDR, because the radar may try to discriminate between targets and electronic countermeasure (ECM) signals. The SFDR will be limited depending on the ENOB, nonlinearity of components and the noise.



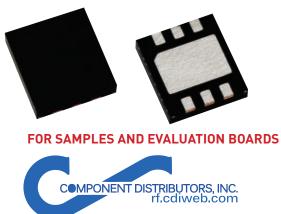
▲ Fig. 5 MATLAB[®] display of a SDR detecting a single target at a range of 2000 m and moving at −25 m/s.





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While high signal fidelity DRFMs with coherent target echo returns may be suitable for radar tests, the use of a DRFM with a user interface to test a broad variety of signal conditions and scene effects may be limited. This very dedicated equipment comes at a price and perhaps, with limited flexibility to thoroughly test the functional parameters of the radar.

Commercial Off-the-Shelf (COTS) Test and Measurement Equipment

COTS test and measurement equipment is also able to generate radar targets, in a similar fashion as DRFMs, by RF down conversion, baseband digital signal processing and RF up conversion.

While an RF signal analyzer and RF signal generator are normally used stand-alone, the two instruments can operate as a radar target generator when used together. The radar target generator uses the signal analyzer as the receiver and the signal generator as the transmitter.

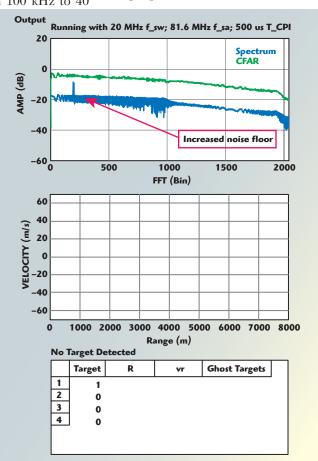
A COTS system, as shown in *Figure 4*, operates from 100 kHz to 40

GHz and will process any type of RF radar signal in this frequency range with up to 160 bandwidth. MHzThe signal analyzer converts the coming radar signal to in-phase and quadrature-phase (Î/Q) data. The I/Q data is transferred the baseband input of the signal where generator, time delay, Doppler frequency shift and attenuation are applied as defined by the user. The radar echo signal is then retransmitted to the radar by the signal generator.

One advantage of using COTS measuring equipment is its exceptional RF performance, which is suitable for additional parametric radar tests during research and development or production. The flexible and modular approach allows the vector signal generator and signal and spectrum analyzer to be used in other setups or in a dedicated field installation.

COTS RADAR TARGET GENERATOR DEMO

A software defined radar (SDR) using MATLAB® signal processing can demonstrate the capability of a COTS radar target generator. A single target with a range of 2000 m and velocity of -25 m/sec is created by the radar target generator and "detected" by the SDR. The MATLAB® graphical user interface (GUI) of the radar (see Figure 5) shows the spectrum (top), range-Doppler map (middle) and target list (bottom). The spectrum plot shows a single local maxima whose power is higher than the constant false alarm rate (CFAR) threshold. By measuring the beat frequency, the range and radial velocity are calculated, which match the target created by the radar target generator.



for additional para- A Fig. 6 Display of the SDR detecting the same target in the metric radar tests presence of a CW frequency-modulated interfering signal.



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The COTS radar target generator can generate up to 20 targets in different range-Doppler cells. The signal generator also has multiple RF sources, making it possible to test the radar in the presence of interference, such as cellular or other services. Figure 6 shows the same radar target with a second, frequency-modulated continuous-wave signal. The noise floor is significantly higher. While the radar echo signal can still be observed visu-

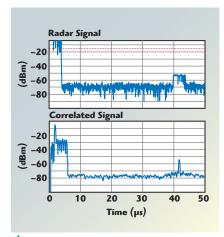
ally, the CFAR threshold is too high for an automatic detection.

In addition to testing the functional performance of the radar, the COTS target generator can help assess modern electronic protection measures in the radar, such as detecting the presence of a DRFM used as a jammer. An example of the importance of this occurred in mid-2014, when several aircraft vanished from ATC radar screens in Europe, which occurred

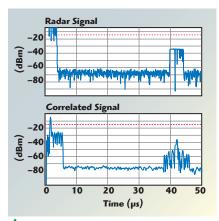
coincidentally with military exercises.8

A phase-modulated radar waveform, such as a Barker code, can be used to test the performance of the radar's signal processing. The Barker code is transmitted and delayed in the radar target simulator. The radar has a very specific baseband waveform, and the radar receiver can detect the fidelity of the echo and, using correlation filters, whether the echo is virtual or real. An uncorrelated signal might result from an ECM system, due to resampling at a different rate, a small number of effective bits in the ADC, phase noise or amplifier distortions in the target simulator. Depending on the DRFM, the generated echo signal fidelity will likely be different than one from a real target.

The radar processes focused on electronic protection can detect differences in fidelity in the returned echo. *Figure 7* shows a Barker-coded



A Fig. 7 Barker-coded radar signal (top), showing the echo after 40 μs, correlated echo signal (bottom).



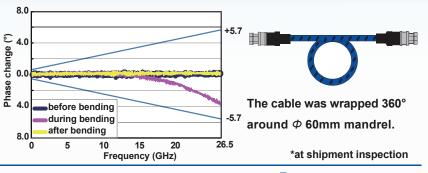
▲ Fig. 8 Barker-coded radar signal (top) with an uncorrelated echo, representing a DRFM return signal created at a different sampling rate (bottom).

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radar signal at the beginning of the measurement and the corresponding radar echo signal attenuated about 50 dB and delayed by 40 µs. The lower plot shows the return signal processed with the correlation filter. *Figure 8* shows the echo signal processed with a different sampling rate, as might occur in a DRFM. The different signal fidelity causes the correlation of the echo signal to change fairly dramatically.

CONCLUSION

The reliability expected of radar systems is extremely high, which is why test and measurement is very important. This article presented several different approaches to using radar target generators to test the entire radar system, including the antenna, transmitter, receiver and signal processing. Comparing the technical performance and economic factors, a perfect balance would bring many

field tests into the lab and reduce the cost of software and hardware testing.

The target generator's RF performance must be better than the performance of the radar and offer a variety of test scenarios. FODLs are still used but lack flexibility, for example in generating range-Doppler-dependent targets. A DRFM overcomes this drawback and offers additional options for generating radar echo signals. However, DRFMs are dedicated solutions, can be costly and are not designed to be as flexible as test equipment. COTS test and measurement equipment offers a wide range of test solutions, from signal and component test and analysis to radar target generation. Such equipment is modular, multi-purpose and flexible; it can be used both as a radar target generator and serve other functions in a labora-

These different radar target generator approaches each have their own advantages, yet all bring parts of the field test into the laboratory, reducing test complexity and lowering costs. They provide repeatability and automated test capabilities.

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References

- "Rohde & Schwarz Enables Comprehensive Automotive Radar Tests with Target Simulator and FM CW Signal Analysis," press release, www.rohde-schwarz.com/ad/ press/automotive, October 2014.
- K.P. Jackson et. al., "Optical Fiber Delay-Line Signal Processing," IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-33, No. 3, pp. 193–210, March 1985.
- K. Ogawa, "Considerations for Single Mode Fiber Systems," Bell Syst. Tech. Journal, Vol. 61, pp. 1919–1931, 1982.
 N. Friedman, "The Naval Institute Guide
- N. Friedman, "The Naval Institute Guide to World Naval Weapons Systems," 1997– 1998
- "AN/ALQ-165 Airborne Self-Protection Jammer (ASPJ)," www.dote.osd.mil, October 2014.
- Small Business Innovation Research (SBIR), Navy, Topic N131-006, Acquisition Program, "Direct Digital Radio Frequency (RF) Conversion Digital Radio Frequency Memory (DRFM)," 2013.
- S. Heuel and A. Roessler, "Co-existence Tests for S-Band Radar and LTE Networks," Microwave Journal - Military Microwaves, August 2014.
- Reuters, "Jets Vanishing from Europe Radar Linked to War Games," www.reuters.com/ article/2014/06/13/us-europe-airplanessafety-idUSKBN0EO1CW20140613, November 2014.



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Single-Chip Millimeter Wave Radar

G. Klaric Felic, R. J. Evans, Hoa Thai Duong, Hoang Viet Le, J. Li and E. Skafidas

University of Melbourne, Parkville, Australia

In this article we explore the coming consumer radar era, where tiny single-chip radar systems will be available for just a few dollars. These systems will use sophisticated waveform diversity and adaptive signal processing to optimize performance. Automotive radar concepts developed at the University of Melbourne are discussed, including CMOS RF transceivers, waveform and signal processing, and antennas.

he idea of radar is more than 100 years old. In 1900, Nikola Tesla foreshadowed the idea of remotely detecting and locating objects using radio waves. His idea was first demonstrated in Germany in 1904 when Christian Hulsmeyer detected ships using echoes of radio signals.

While the essential idea of radar is simple, the evolution to improve performance and capabilities has been an ongoing technology driver. We believe this trend will accelerate with the emerging capabilities in single-chip millimeter wave radar that are enabled by CMOS scaling (Moore's law) and recent advances in adaptive waveform design.

Interest in consumer applications for radar is not new, of course. In 1993, the IEE held a symposium on this very topic, and low cost, handheld Doppler radar systems are already on the market (e.g., pocket radar). Today, the automotive market is arguably the main opportunity driving innovation in small, low cost millimeter wave radar. Radar systems are installed in many transportation vehicles to assist safety and comfort, providing drivers with information about the distance between vehicles and

obstacles on the road. Radar systems can take another step functionally, by automatically controlling acceleration and braking to avoid collisions.

Sensing systems for "micro" unmanned aerial vehicles (UAV) is another application for small, lightweight, yet high performance radar technology. The availability of tiny and cheap radar systems is likely to open up many new applications, mimicking the transformation following the availability of small, inexpensive GPS systems.

The relentless scaling of semiconductor technology is enabling the move to higher and higher RF frequencies and integrating complete radar systems, with both RF and digital processing, on a single IC. Clever new waveform diversity techniques² with innovations in small antenna technology will lead to highly sophisticated consumer radar systems over the next few years.

SINGLE CHIP RF SYSTEM

The advancement of key techniques and technologies in low cost millimeter wave radio systems has aided the development of automo-



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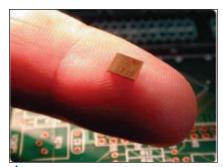
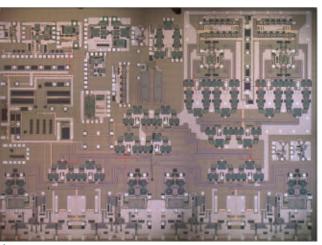


Fig. 1 The single-chip radar transceiver developed by the University of Melbourne.

tive radar sensors in the frequency bands from 60 to 95 GHz. Today, with the rapid evolution of SiGe bipolar and CMOS processes, a 77 GHz automotive radar transceiver can be realized in a single IC (see $\it Figure 1$). The low cost and compact size of the chip are enabling the adoption by low and medium priced cars. $^{3-7}$

Compared with a SiGe bipolar process, CMOS is lower cost, better integrates digital circuitry and benefits from technology scaling. However, the maximum available gain (MAG) at



▲ Fig. 2 Photograph of the single-chip CMOS transceiver die, which contains two transmit and four receive channels and the local oscillator.

millimeter wave frequencies is lower for CMOS, and its low supply voltage limits output power. Therefore, developing a millimeter wave CMOS transceiver is still a challenging task for many researchers. 8–13

The radar sensor on a chip developed by the University of Melbourne is

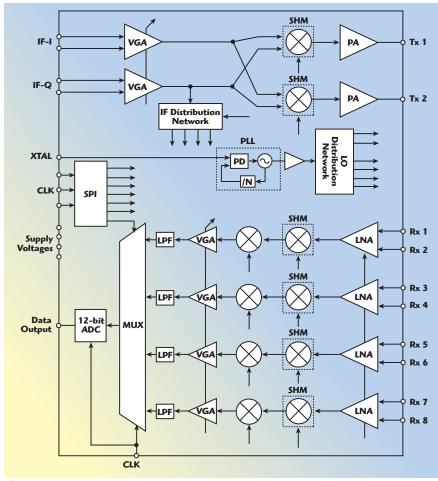
a CMOS transceiver (see Figure 2) suitable for both short and long range sensing and operating in the globally harmonized 76 to 77 GHz band.¹⁴⁻¹⁵ Design objectives were low cost, low power dissipation, compact size, flexibility and ease of use. As shown in the schematic (see Figure 3), the transmitter comprises two variable gain amplifiers (VGA), sub-harmonic mixers (SHM)

and power amplifiers (PA). Four receive channels, supporting eight separate receive antennas, each contain a chain of switched low noise amplifiers (LNA), SHMs, VGAs, and lowpass filters (LPF). The IF outputs from the four receive channels are multiplexed into a single 12-bit, 100 MSPS analog-to-digital converter (ADC). All the RF components – passives, amplifiers, mixers, oscillators – are fabricated on the 7.2 × 5.5 mm chip.

In the 76 to 77 GHz band, the transceiver has demonstrated 10 dBm single sideband output power¹⁴ with LO-RF leakage power of -35 dBm. Receiver sensitivity is better than -100 dBm.¹⁵ The gain of each receive channel is adjustable in 5 dB steps from 0 to 80 dB.

WAVEFORMS AND SIGNAL PROCESSING

Radar design was put on a sound theoretical footing in 1953 when Philip Woodward developed the radar ambiguity function at TRE in England. 16 His work was based on the matched filter developed by Dwight North in 1943 at RCA Labs in Princeton, N.J. Woodward's ambiguity function characterizes the performance of a matched filter radar for any particular transmitted waveform. Unfortunately, it is not possible to precisely synthesize a transmit waveform based on the desired ambiguity function. Significant research has been devoted to the synthesis problem, including the work of Wilcox¹⁷ on the group theoretic foundations of ambiguity theory, which enabled synthesis of a certain restricted class of waveforms. Suss-



▲ Fig. 3 Schematic showing the functional complexity of the single-chip radar transceiver.

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550 U	0301	100 nF	16 KHz to 40+ GHz	<0.4 dB typ.	6.3 WVDC	No
550 L	0402	100 nF	16 KHz to 40+ GHz	<0.5 dB typ.	16 WVDC	Yes
550 S	0603	100 nF	16 KHz to 40+ GHz	<1 dB typ.	50 WVDC	Yes



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man¹⁸ and Vakman¹⁹ subsequently proposed Hilbert-Schmidt operator approximation techniques to approximately synthesize waveforms with specified ambiguity properties. Work in this direction is continuing.²⁰ Progress on this difficult yet deeply important problem has taken on a new flavor in recent years under names such as waveform diversity, adaptive waveforms and waveform scheduling.2 Digital waveform generation and fast adaptable digital matched filter implementation allow waveform diversity techniques to be implemented even in low cost, single-chip radar systems.

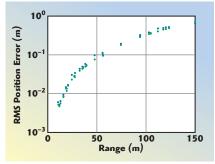
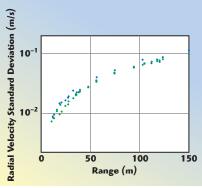


Fig. 4 Position error as a function of range.

The radar-on-a-chip developed at the University of Melbourne employs adaptive digital matched filtering and scheduling of advanced multi-frequency coded waveforms to reduce clutter, mitigate against interference and reduce the computational load in the digital signal processing. Waveforms employed include sections of fast ramping linear FM (LFM), long random stepped frequency waveforms and bursts of CW.

Typical radar performance is demonstrated with an automotive scenario



▲ Fig. 5 Doppler estimation error as a function of range.

consisting of 25 oncoming point scatterers, centered on, and five targets, centered around the field of view. All scatterers and targets have unity radar cross section (RCS), and the speed of each target and scatterer is chosen randomly within the range of typical automobile speeds. The performance of the radar is shown in *Figure 4*, the range estimation error as a function of target range, and *Figure 5*, the Doppler estimation accuracy.

As radar sensing becomes ubiquitous in consumer applications, the spatial density of users utilizing a common frequency band will increase vastly. While it is fortunate that a range of techniques for mitigating interference has been developed for use in wireless communications, the requirements for radar pose distinct new challenges.

ANTENNA SYSTEM

The antenna is a critical element in all radar systems. For automotive applications, the requirements are especially challenging: high gain and low loss for best performance traded off with small size, low cost and aesthetically pleasing for vehicles. The additional need for the radar to have wide angle visibility requires the use of multi-beam or scanning antennas and solutions based on digital beam forming with multiple antenna elements.

The design of the radar antenna depends on the specifications for directivity/gain, angular resolution and accuracy. These parameters determine the ability of a radar sensor to detect a target at the required distance, resolution and accuracy. The radar equation defines the required antenna directivity/gain necessary to detect an object at distance R

$$G_T G_R = \frac{R^4 P_R \left(4\pi\right)^3}{P_0 \lambda^2 \sigma} \tag{1}$$

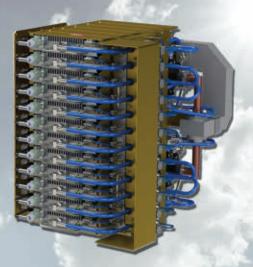
where P_0 is the feeding power of the antenna, σ is the radar cross section of the object, λ is the wavelength and the receiving power P_R is determined by the minimum signal-to-noise ratio. The ability of a radar system to determine the exact position of an object is based on the half power (3 dB) antenna beamwidth. For a linear array, this can be estimated by



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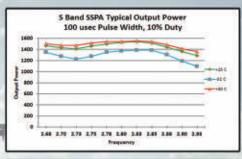
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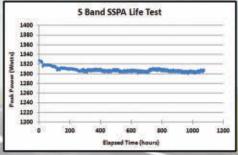
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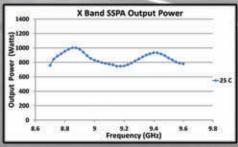
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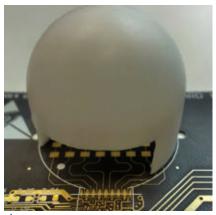
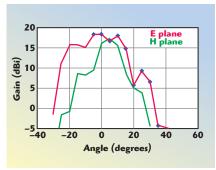
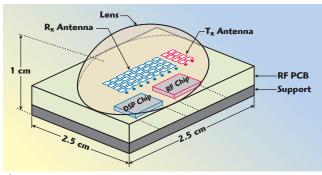


Fig. 6 Photograph of the microstrip series-fed patch array and lens.



▲ Fig. 7 Measured antenna gain of one channel at 77 GHz.



▲ Fig. 8 Concept design of the integrated radar system. The single-chip RF transceiver, DSP, patch antenna array and lens are integrated on a PCB to minimize cost.

$$\Delta\theta_{\rm 3dB} = \frac{\lambda}{\mathrm{d}\cos(\theta)\sqrt{\mathrm{M}^2 - 1}} \tag{2}$$

where M is the number of antenna elements, d is distance between the antennas and θ is the beam angle towards the normal of the air-dielectric interface. The angular accuracy can be determined with the signal-tonoise ratio of the system as

$$\delta\theta_{3dB} = \frac{\Delta\theta_{3dB}}{\sqrt{2S/N}}$$
 (3)

Mid and longrange radar systems have smaller beamwidth than shortrange antennas. For 77 GHz long-range radar, 3 to 4 degree beamwidths typically required. This results in very large arrays gains around 30 dB, which led the first automotive radar systems for long-

range detection to adopt parabolic reflector or lens antennas.²¹ The advantage of lens over reflector antennas is that the feed is not in the path of the secondary rays; however lens antennas are typically thicker, heavier and more difficult to construct. The need for small sensor depth in vehicles limits their use.

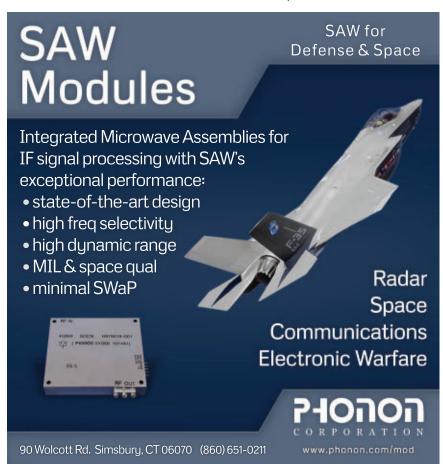
The University of Melbourne radar sensor uses a dielectric lens antenna illuminated by series-fed patches, achieving both low cost and high gain for mid and long-range applications. Figure 6 shows the lens antenna with cascaded microstrip patch elements interconnected by half-wavelength high impedance transmission lines. The patch element design is based on the transmission line model and the equivalent circuit concept.^{22–23} The lens is hemispherical (plano-convex) and made of a low dielectric constant material such as Teflon ($\varepsilon_r = 2.2$), which is low loss and easy to manufacture. The lens provides a support structure for the substrate containing the patch antenna elements.

The antenna gain and the 3 dB beamwidth of the dielectric lens depend on its size. The correlation between the radius, r, of the lens and the 3 dB beamwidth (in the elevation plane) for a uniform illuminated circular lens is given by ²⁴

$$\theta_{3dB} = 57 \frac{\lambda}{2r} \tag{4}$$

where λ is the operating wavelength.

The measured elevation (H plane) and azimuth (E plane) radiation patterns of the antenna are shown in *Figure 7*. The maximum gain at 77 GHz is 18 dB, and the 3 dB beamwidth is 10 degrees in elevation and 18 degrees in azimuth.



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INTEGRATED RADAR

Our vision of the integrated radar system is shown in *Figure 8*. An RF printed circuit board (PCB) contains the RF transceiver IC, digital signal processor (DSP) and printed antenna array. The lens extends above the PCB, attached to the board and providing a protective cover for the complete assembly. The ICs are flip-chip attached to the RF PCB.

Antenna scanning is achieved with phased arrays and digital beam forming. The phase shifting method connects antenna elements or sub-arrays to phase shifters, enabling beam scanning. At millimeter wave frequencies, this approach can be complex, lossy and costly. With digital beam forming, several antenna elements or sub-arrays are successively switched to a receiver or transmitter or, alternatively, connected to multiple transmit—receive circuits.

CONCLUSION

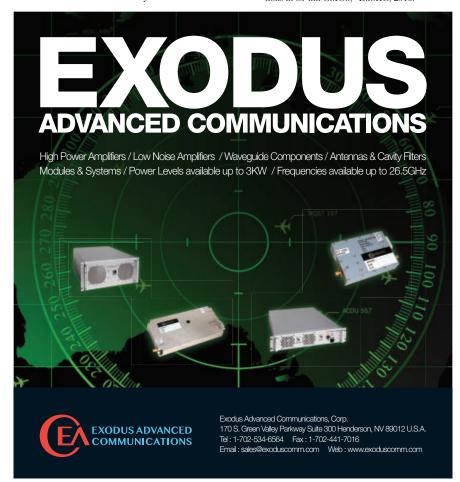
This article describes the concept and development of a low cost, 77 GHz automotive radar system, including a single-chip CMOS millimeter wave transceiver. The architecture shown in Figure 8 will enable a consumer radar revolution as a result of advances in CMOS semiconductor processes and radar algorithms.

The performance achieved from this radar matches standard radar theory, with the potential for further improvement in the information that can be extracted from a radar system. Our approach to this ²⁵ builds on Lebedev's work ²⁶ on the information carrying capacity of a bosonic field. ■

References

- IEEE Symposium on Consumer Applications of Radar and Sonar, London, UK, May 1993.
- M. C. Wicks, E. L. Mokole and S. D. Blunt, "Principles of Waveform Diversity and Design," SciTech, 2010.
- M. Hartmann, C. Wagner, K. Seemann, J. Platz, H. Jager and R. Weigel, "A Low-Power Low-Noise Single-Chip Receiver Front-End for Automotive Radar at 77 GHz in Silicon-Germanium Bipolar Technology," pp. 149–152.
- J. Lee, Y.A. Li, M.H. Hung and S.J. Huang, "A Fully-Integrated 77 GHz FMCW Radar Transceiver in 65-nm CMOS Technology," Vol. 45, No. 12, pp. 2746–2756, 2010.
- H. T. Duong, H. V. Le, A. T. Huynh, R. J. Evans and E. Skafidas, "Design of a High Gain Power Amplifier for 77 GHz Radar Automotive Applications in 65-nm CMOS," EuMIC, 2013.

- H. V. Le, H. T. Duong, A. T. Huynh, R. J. Evans and E. Skafidas, "A CMOS 77 GHz Radar Receiver Front-End," EuMIC, 2013.
- A. Natarajan, A. Komijani, X. Guan, A. Babakhani and A. Hajimiri, "A 77 GHz Phase-Array Transceiver with On-chip Antennas in Silicon: Transmitter and Local LO-path Phase Shifting," *IEEE J. Solid-State Circuits*, Vol. 41, No. 12, pp. 2807–2819, December 2006.
- U. R. Pfeiffer, S. K. Reynolds and B. A. Floyd, "A 77 GHz SiGe Power Amplifier for Potential Applications in Automotive Radar Systems," *IEEE* RFIC Symp., pp. 91–94, June 2004.
- A. Komijani and A. Hajimiri, "A Wideband 77 GHz, 17.5 dBm Power Amplifier in Silicon," IEEE Journal of Solid-State Circuits, Vol. 41, No. 8, pp. 1749–1756, August 2006.
- T. Suzuki, Y. Kawano, M. Sato, T. Hirose and K. Joshin, "60 and 77 GHz Power Amplifier in Standard 90 nm CMOS," ISSCC Digest Technical Papers, pp. 562–563. February 2008.
- B. Wicks, E. Skafidas and R. Evans, "A 77-95 GHz Wideband CMOS Power Amplifier," Microwave Integrated Circuit Conference, pp. 555-559. February 2008.
- J. Lee, C. C. Chen, J. H. Tsai, K. Y. Lin and H. Wang, "A 68-83 GHz Power Amplifier in 90 nm CMOS," *IEEE MTT-S International Microwave Symposium Digest*, pp. 437–440, June 2009.
- Y. A. Li, M. H. Hung, S. J. Huang and J. Lee, "A Fully-Integrated 77 GHz FMCW Radar System in 65 nm CMOS," ISSCC Digest Technical Papers, pp. 216–217, February 2010.
- Viet Hoang Le et al., "A CMOS 77-GHz Receiver Front-End for Automotive Radar," *IEEE Transactions Microwave Theory and Techniques*, Vol. 61, No. 10, pp. 3783–3793.
- Hoang Viet Le et al., "A CMOS 77 GHz Radar Receiver Front-End, 8th EuMIC, Nuremberg, Germany, October 2013.
- P. M. Woodward, "Probability and Information Theory with Applications to Radar," Pergamon Press, 1953.
- C. H. Wilcox, "The Synthesis Problem for Radar Ambiguity Functions," MRC Technical Report 157, Mathematics Research Centre, U.S. Army, University of Wisconsin, Madison, 1960.
- S. M. Sussman, "Least-Square Synthesis of Radar Ambiguity Function," *IRE Transactions on Infor*mation Theory, Vol. IT-8, No. 3, 1962.
- D. E. Vakman, "Sophisticated Signals and the Uncertainty Principle in Radar," Springer-Verlag, 1968.
- S. Lloyd, "Enhanced Sensitivity of Photo-Detection via Quantum Illumination," Science, Vol. 321, September 2008, pp. 1463–1465.
- Bradley G. Porter, Leonard L. Rauth, John R. Mura and Steven S. Gearhart, "Dual-Polarized Slot-Coupled Patch Antennas on Duroid with Teflon Lenses for 76.5 GHz Automotive Radar Systems," *IEEE Transactions on Antennas and Propagation*, Vol. 47, No. 12, December 1999.
- J. Freese and R. Jakoby, "Synthesis of Microstrip Series-Fed Patch Arrays for 77 GHz Sensor Applications," Microwave Conference, 2000 Asia-Pacific, 2000, pp. 29–33.
 B. B. Jones, F. Y. M. Chow and A. W. Seeto, "The
- B. B. Jones, F. Y. M. Chow and A. W. Seeto, The Synthesis of Shaped Patterns with Series-Fed Microstrip Patch Arrays," *IEEE Transactions on Antennas and Propagation*, Vol. AP-30, No. 6, November 1982.
- T. Binzer, M. Klar and V. Gross, "Development of 77 GHz Radar Lens Antennas for Automotive Applications Based on Given Requirements," INICA, 2nd International ITG Conference on Antennas, 2007, pp. 205–209.
- tennas, 2007, pp. 205–209.
 25. R. J. Evans et al., "Consumer Radar: Technology and Limitations," International Radar Conference, Adelaide, September, 2013, pp. 21–26.
- D. Lebedev and L. Levitin, "Information Transmission by Electromagnetic Field," *Information and Control*, Vol. 9, No. 1, pp. 1–22, 1966.





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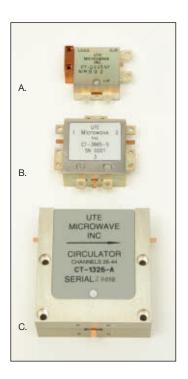
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Patrick Hindle and Gary Lerude Microwave Journal, *Norwood*, *Mass*.

After serving as something of a cash cow for HP and then Agilent Technologies, the electronic measurement business is now charting its own course as an independent company – Keysight Technologies. Microwave Journal was honored to be the first of the industry trade media to visit and tour Keysight's new Santa Rosa headquarters. This special report summarizes what we saw and learned.

eborn. As they rang the bell at the New York Stock exchange on November 3, Keysight Technologies returned to its roots in electronic measurement, the last step in splitting off from Agilent Technologies to become a separate company. Grown out of Bill Hewlett's and Dave Packard's audio oscillator, invented in the famous garage in Palo Alto in 1939, HP became so large that it split in 1999, with the electronics group becoming Agilent Technologies. Agilent grew its two businesses in electronic measurement and life sciences into dominant segments in their respective markets. Yet each was different. With time, it made sense to split the two, so each could best serve its own market and needs.

Keysight is based at the Santa Rosa campus that Hewlett Packard established in 1972. They are among the largest employers in the city, with 1250 employees and 400 contractors occupying four buildings. Since 2008, the company has invested \$100 million in the site, blending funding with values that make Keysight a model of

corporate citizenship: an onsite school for employees' children, offering classes from kindergarten through second grade; 3 acres of solar panels generating 1.8 million kWh per year; onsite recycling that reuses about 70 percent of their water; employee gardens that provide fresh food

for the on-site chefs to feature in the dining areas; and workout facilities that include a gym, baseball and soccer fields.

Keysight carries on the legacy of "the HP way," management practices such as the open door policy (none of the offices have doors, including the CEO's), collaborative workspaces (most of the cubical walls are low to facilitate interaction) and flexible work schedules. Employees are encouraged to start clubs and interest groups and can apply for company funding to hold events and meetings, requests which the CEO personally approves. Employees generously support charitable and community needs, volunteering more than 50,000 hours a year. The company supports their efforts with paid time off. In 2013, Santa Rosa employees donated some \$320 thousand to charitable causes, funds that were matched by the company. Keysight and its foundations strongly support science, technology, education and math (STEM), contributing more than \$10 million to STEM programs, universities and non-profits in 2013.

Building 1 on the sprawling campus includes an area commemorating the firm's 75-year history, including a large wall listing each of the patents in their portfolio (see *Figure 1*) as well as displays of the test equipment that is their raison d'être. An HP200A audio oscillator – the product that launched HP – is fully functional, with glowing tubes and a red power light on the front panel (see *Figure 2*). It is joined by a progression of test systems produced over the years, with a large timeline that spans the hallway and commemorates the key events in the company's history. Adjacent walls are deco-



▲ Fig. 1 Wall listing all Hewlett Packard – Agilent – Keysight Technologies' patents since 1939.

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SpecialReport



Fig. 2 Fully functional HP200A audio oscillator, the first product offered by HP.

Fig. 3 Photos taken by employees hang on the walls at Keysight Technologies' headquarters in Santa Rosa.

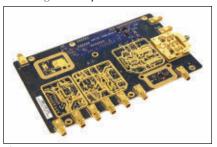


Fig. 4 Integrated RF subassembly showing Keysight's chip-on-board technology. Connectorized thin-film modules, such as the one on the right side of the board, are used for circuits operating well into millimeter wave frequencies.

rated with stunning photos taken by employees, the winners of a monthly contest (see *Figure 3*).

STRATEGY

Keysight is focusing on three broad markets: 1) communications 2) aerospace and defense, and 3) industrial, computers and semiconductors. Each segment offers growth, from such drivers as mobile data, more connections, higher data rates and defense modernization. To broaden its product portfolio from the long-standing test and measurement "boxes," Keysight is expanding its offerings in modular, software and complete system solutions.

One recent example of the latter is the collaboration between Kevsight and Cascade Microtech to offer a wafer-level measurement system. This comprises all hardware and software as well as initial setup, calibration, training and service. Cascade provides a single point-of-contact for all technical support. This complete system solution was prompted when both companies noticed that many customers let these large capital items sit for months awaiting setup and qualification, simply because of a lack of manpower or missing accessories. So Keysight and Cascade Microtech teamed up to solve the problem and provide more value to their customers. They also developed a software platform, WaferPro Express, to automate on-wafer measurements

> and manage a device modeling database data analysis, model extraction and verification.

To serve the rollout of 4G and adoption of heterogeneous networks, Keysight is develop-

ing products such as one-box testers like the UXM, for R&D, and EXM for manufacturing. With the Internet of Things (IoT) and 5G on the horizon, the company is engaged in industry research and standards development, which will define future test and measurement needs.

VERTICAL INTEGRATION

Keysight is known for high quality and high performance test equipment, which is a result of attention to detail at every step of design, manufacturing and test. Almost all of their microwave devices are produced in Santa Rosa, including GaAs and InP MMICs and YIG spheres. Their III-V wafer fab focuses on performance, reliability and long lifetimes, not volume. The fab runs about 2500 three-inch wafers per year across 13 processes that include MESFET, PHEMT and HBT devices. Keysight operates several MBE systems to tailor device epitaxy and optimize performance.

To support the unique needs of test and measurement equipment, they develop custom packaging solutions that include thin-film deposition, machining and sealing. Internal semi-automated and fully automated die-attach and wire bonding manufacturing lines serve both development and production.

A good example of Keysight's RF expertise is the development of RF assemblies using a high performance, chip-on-board technology that can integrate an RF front end onto a single

laminate board (see Figure 4). This packaging technology includes the capability to incorporate walls to shield sensitive RF circuits. A typical board is highly integrated, containing 35 to 40 RF devices and hundreds of other components. Compared with the traditional approach of thin-film circuit assemblies in machined and plated housings, the chip-on-board laminate reduces size, weight and cost while maintaining even improving – performance.

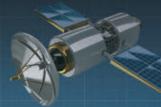
The laminate board works to frequencies well beyond 26.5 GHz and traditional hybrid modules can be used in concert with the laminate to deliver performance far into the millimeter wave range. Modules can be mounted onto the laminate board, with the module RF signal connected to the laminate before or after frequency conversion. Figure 4 shows a high frequency module with a precision, ruggedized connector on the right side of the laminate board.

To automate the final testing of Keysight's test and measurement equipment, five company engineers developed a robotic line that moves each instrument into and out of various test stations, tracking the test flow, measured data and pass/fail results. DC and RF connections to the unit under test are made automatically, and electrical tests can be performed at hot and cold temperatures. When a test is complete, the robotic cart returns to the station and moves the unit to the next test. Status and data are available online, allowing employees to monitor the results from anywhere. Two robotic lines run in Santa Rosa, and the company's production facility in Malaysia has eight.

CULTURE AND STRATEGY

Management guru Peter Drucker is credited with coining the maxim "culture eats strategy for breakfast," meaning a misaligned culture can undermine the best strategy. After a day walking the halls and speaking with numerous Keysight employees, we left Santa Rosa feeling that the people are proud, energetic and enthusiastic about the future - which makes the culture a strong and secure foundation for Keysight's strategy. The energy and enthusiasm felt like a startup, yet one with a proud, 75-year history. A unique \$3 billion startup has indeed been reborn.

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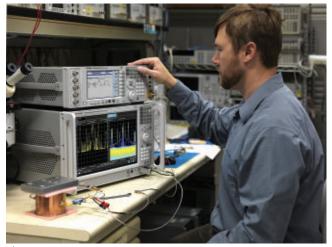
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New Signal Generation Techniques Enhance EW Environment Simulation

Keysight Technologies formerly Agilent Technologies electronic measurement business Santa Rosa, Calif.

In recent years, various architectures have been used to develop the agile, wideband signal sources needed for threat simulation in electronic warfare (EW) applications. Similar approaches have been used to create local



▲ Fig. 1 The Keysight UXG agile signal generator (top) is a powerful building block as either a dependable LO or a scalable threat simulator.

oscillators (LO) and RF pulse generators that can quickly switch over wide frequency and amplitude ranges.

These ideas were central to the creation of the new Keysight UXG agile signal generator shown in *Figure 1*. The UXG architecture uses a direct digital synthesizer (DDS) and new switching technology to create a signal generator ideally suited to applications that need an agile LO or require highly realistic simulation of EW environments. The DDS is built around a digital-to-analog converter (DAC) that was developed by Keysight to achieve dramatic improvements in dynamic range and phase noise.

DESIGNING FOR PURITY, AGILITY AND SPEED

The performance and capabilities of the UXG are based on three innovative technologies: DDS-based signal generation with an exceptional combination of purity and bandwidth, from 10 MHz to either 20 or 40 GHz; solid-state switches that change output levels in as little as 180 ns over large amplitude rang-

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Fixed Coaxial Attenuators

Model	Frequency (GHz)	Avg. Power (W)	Peak Power (kW)	Available dB Values	SWR	Connector Type Available
59	DC to 2.5	100	10	10, 20, 30, 40	1.15	Type N
72	DC to 4.0	50	5	3, 6, 10, 20, 30	1.20	Type N
253	DC to 6.0	550	10	10, 20, 30, 40	1.10 to 1.20*	SMK (2.92mm) or N
257	DC to 6.0	250	10	10, 20, 30, 40	1.10	SMK (2.92mm) or N
258	DC to 6.0	400	10	10, 20, 30, 40	1.10 to 1.25*	SMK (2.92mm) or N
268	DC to 6.0	100	10	6, 10, 20, 30, 40	1.10 to 1.15*	SMK (2.92mm) or N
284	DC to 10.0	50	5	3, 6, 10, 20, 30, 40	1.10 to 1.30*	SMK (2.92mm) or N

Coaxial Terminations

Model	Frequency (GHz)	Avg. Power (W)	Peak Power (kW)	SWR	Connector Type Available
1441	DC to 4.0	50	5	1.20	Type N
1470	DC to 6.0	100	10	1.20	SMK (2.92mm) or N
1471	DC to 6.0	250	10	1.20	SMK (2.92mm) or N
1472	DC to 6.0	400	10	1.20	SMK (2.92mm) or N
1473	DC to 6.0	400	10	1.20	SMK (2.92mm) or N
1476	DC to 10.0	50	5	1.25 to 1.40*	SMK (2.92mm) or N

^{*} Varies with frequency.

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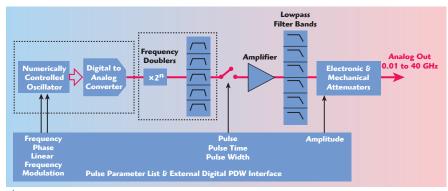
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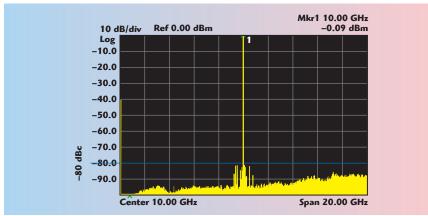
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ProductFeature



▲ Fig. 2 The architecture of the UXG enables accurate simulation of complex signal scenarios through fast switching, phase repeatability and extensive pulse-modulation capabilities.



▲ Fig. 3 In this 20 GHz spectrum measurement, a 10 GHz CW signal from the UXG signal generator exhibits high dynamic range, with a low noise floor and minimal spurious signals.

es and with accurate time alignment; and direct support for pulse descriptor words (PDW), the natural language of EW engineers, that enables efficient creation of complex and precise outputs. The block diagram shown in *Figure 2* illustrates the DDS-based architecture of the UXG. A high speed DAC is the heart of the DDS. An array of doublers and filters is used to multiply the signal up to a maximum

frequency of 40 GHz. The DAC covers an octave centered at 1 GHz and provides dramatic improvements in dynamic range and phase noise. This results in very high purity signals, as shown in *Figure* 3.

This performance is available with industry-leading switching speed and very low latency for changing frequency. Frequency can be updated in as little as 180 ns. Depending on the selected instrument mode, the delay between an external command and frequency change (i.e., latency) is as little as 370 ns. The UXG can also generate wide chirps 10 to 25 percent of the carrier frequency.

Comprehensive EW threat simulation needs amplitude agility that matches the source's frequency agility. This requires coordinated switching from solid-state attenuators, which the UXG does using "nanoFET" MMICs invented and manufactured by Keysight. These new switches are designed for microwave and millimeter wave frequencies, with fast settling to minimize distortion of the pulse shape. The resulting 90 dB agile amplitude range can be used between output levels from 0 to -130 dBm, which handles a wide range of threat scenarios.

To optimize cost and capability for different applications, the solid-state agile attenuator is optional.

For some threat environment scenarios, it is essential to maintain specific phase and frequency rela-

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tionships while signals are pulsed, frequency-hopped or interleaved in a sequence. The UXG produces any phase or frequency trajectory without limiting frequency or amplitude agility. It also maintains any desired relationships as frequency, amplitude and pulse characteristics are changed or as signals are pulsed on and off.

Multiple UXGs can be linked through clocks and triggers to provide phase coherence across the sources, making it possible to simulate steerable beam antennas or produce angle-of-arrival trajectories to evaluate direction-finding receivers.

AVOIDING SURPRISES LATE IN THE DEVELOPMENT PROCESS

The EW environment is an ongoing contest between the development and implementation of improved systems and the analysis and countermeasures needed to defeat those systems.

As implemented in the UXG, the DAC-based DDS architecture offers compelling advantages for EW appli-

cations, whether the need is for agile LO generation or PDW-based EW environment simulation:

Signal quality – The UXG generates signals with low spurious and without the phase noise pedestal that is characteristic of systems that use phase-locked loops (PLL) instead of DDS.

Very high agility in frequency, amplitude and phase – All three aspects of the signal output can be updated in as little as 180 ns.

Support of multiple signals and complex scenarios – Sample sequences can represent multiple emitters from a single source.

Phase repeatability – Signalgeneration calculations include phase accumulators programmed with any desired phase relationship.

Good match to evolving threats – The agility and flexibility of the UXG allows it to accurately simulate the equivalent characteristics of the modern threat environment and adapt as these threats change.

Simpler path from pulse requirements to actual signal output – The

UXG can directly reproduce complex dynamic and pulsed signals by creating them mathematically from the desired pulse characteristics.

This last point is important: the UXG directly understands PDWs. Each word describes all the parameters of an individual pulse: frequency, duration, amplitude, chirp rate and more. Tables of PDWs can be transferred to UXG memory and complex sequences produced at high speed. Individual pulses can be as narrow as 10 ns, with 3 ns rise and fall times and an 90 dB on/off ratio. Marker outputs are available to coordinate execution of PDWs with other devices, and sequences of PDWs can be triggered and regulated by sending external triggers to the UXG.

With these capabilities, the UXG brings extensive and realistic testing to earlier stages of the design process, allowing engineers to optimize and verify system performance before the expense, potential delay and poor repeatability of field testing. It also significantly reduces the time from gathering new signal intelligence to creating realistic simulated threats.

GETTING CLOSER TO REALITY

In development and mission data reprogramming, better testing performed sooner enables deeper confidence in the performance of EW systems. The Keysight UXG agile signal generator lets EW engineers create complex scenarios when they need them.

Off the shelf, the UXG is a powerful building block, whether the need is for a dependable LO or a scalable threat simulator. Because the UXG is fluent in the language of EW systems, it accelerates the conversion of new intelligence into up-to-date signal scenarios. With unmatched performance in switching speed and phase noise, the UXG makes it possible to generate increasingly complex simulations and get closer to reality.

VENDORVIEW

Keysight Technologies Inc.

Santa Rosa, Calif. www.keysight.com/find/UXG.



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- Pulse modulation
- Low harmonics (-66 dBc)
- USB control

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- USB control



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HUBER+SUHNER Herisau, Switzerland

he increasing volume of wireless data year after year poses the challenge of providing enormous data capacity while meeting customer expectations for service quality and operator requirements for cost-effective service delivery. As mobile data traffic continues to grow, small cells in heterogeneous networks are increasingly seen as vital to meeting the challenge. Since copper or fiber is rarely available to connect these cells with the network, unobtrusive and cost-efficient wireless backhaul is essential.

SENCITY®Matrix flat antennas address these issues and offer solutions. The latest additions to the series are highly directional V-and E-Band antennas for 60 and 70/80 GHz. The V-Band antenna covers 57 to 66 GHz, while the E-Band antenna addresses 71 to 76 and 81 to 86 GHz. Smaller than conventional antennas, the SENCITY®Matrix antennas are low profile, light weight and easily aligned.

COMMUNITY FRIENDLY

The small size of the antennas allows operators to access rooftop, wall and street-level sites that are often not viable for traditional parabolic antenna systems because of technical, environmental or planning restrictions. The "community friendly" design of the SENCITY®Matrix avoids aesthetic concerns for street-level installations on lamp posts, street signs and kiosks, which are the primary choices for small cell sites. The antenna's flat shape and compact design significantly reduces the visual impact and total cost of ownership while providing excellent electrical performance.

In order to meet the high gain requirement for millimeter wave backhaul systems, the flat antennas include an ad-hoc distribution network that feeds the array elements. This network combines innovative elements to achieve a relative bandwidth as large as 20 percent. SENCITY®Matrix antennas substitute the lossy planar dielectric lines and elements with hollow waveguide structures that drastically reduce signal attenuation while maintaining an elegant low profile (5 to 10 mm).

The boresight gain of the antennas inherently coincides with the normal axis of the radiator. This enables the use of optical techniques (e.g., camera or laser) for quick and easy radio alignment. The design of the flat antenna also ensures 0° beam squint electromagnetic radiation over all working frequencies. This means

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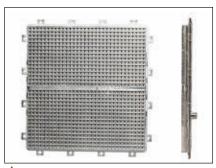
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KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights

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ProductFeature



▲ Fig. 1 A 60 GHz flat antenna without a housing, which can easily be integrated into a customer's radio housing.



▲ Fig. 2 The "lotus effect" cover is water repellent, providing super hydrophobic characteristics.

no compromise among different frequency bands, and all channels simultaneously benefit from the optical alignment.

The intrinsic isotropic thermal expanding behavior of the SENCITY® Matrix material guarantees a very stable radiation characteristic. Changes in temperature produce only a minimal frequency shift: ±150 MHz from -45° to +75°C. This is well within the extremely wide bandwidth of the antennas.

ENVIRONMENTAL FACTORS

The small size, mechanical robustness and flatness of the antennas facilitate integration into radios and provide maximum possible freedom for the mechanical design team (see Figure 1). The integration of the antenna into the radio protects it from exposure to environmental conditions such as dust, water and ice, which can cause issues at the interface between radio and antenna in traditional split-mount setups. An ingenious attachment of the antenna to the power amplifier enables direct heat transfer between the radio and antenna, preventing surface icing and the creation of water droplets.

A "lotus effect" water repellent cover (shown in *Figure 2*) provides super hydrophobic characteristics to SENCITY®Matrix antennas. Its contact angle of ~155° is far greater than the 80° to meet the HC Class 1 standard in STRI Guide 92/1 and the 90° in ASTM-D7334, 2013. This cover minimizes the impact of water and maximizes the radio link performance.

The antennas are manufactured out of metallized plastic parts produced by high precision injection molding.

The highly directional E/V-Band flat antennas are very low profile, lightweight and easily aligned. SENCITY®Matrix antennas provide key distinguishing benefits in mobile backhaul applications. The biggest contributor to reduced operating expense is the unobtrusive appearance of these planar antennas, which facilitates site acquisition and reduces tower rental cost.



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Directional Couplers Up to 60 GHz



Frequency Range			Directivity (dB) min.	VSWR max.	Model Number
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1.0-4.0 GHz	0.35	± 0.50 dB	23	1.20:1	CS*-04
0.5-6.0 GHz	1.00	± 0.80 dB	15	1.50:1	CS10-24
2.0-8.0 GHz	0.35	± 0.40 dB	20	1.25:1	CS*-09
0.5-12.0 GHz	1.00	± 0.80 dB	15	1.50:1	CS*-19
1.0-18.0 GHz	0.90	± 0.50 dB	15 12	1.50:1	CS*-18
2.0-18.0 GHz	0.80	± 0.50 dB	15 12	1.50:1	CS*-15
4.0-18.0 GHz	0.60	± 0.50 dB	15 12	1.40:1	CS*-16
8.0-20.0 GHz	1.00	± 0.80 dB	15 12	1.50:1	CS*-21
6.0-26.5 GHz	0.70	± 0.80 dB	13	1.55:1	CS20-50
1.0-40.0 GHz	1.60	± 1.50 dB	10	1.80:1	CS20-53
2.0-40.0 GHz	1.60	± 1.00 dB	10	1.80:1	CS20-52
6.0-40.0 GHz	1.20	± 1.00 dB	10	1.70:1	CS10-51
6.0-50.0 GHz	1.60	±1.00 dB	10	2.00:1	CS20-54
6.0-60.0 GHz	1.80	± 1.00 dB	07	2,00:1	CS20-55

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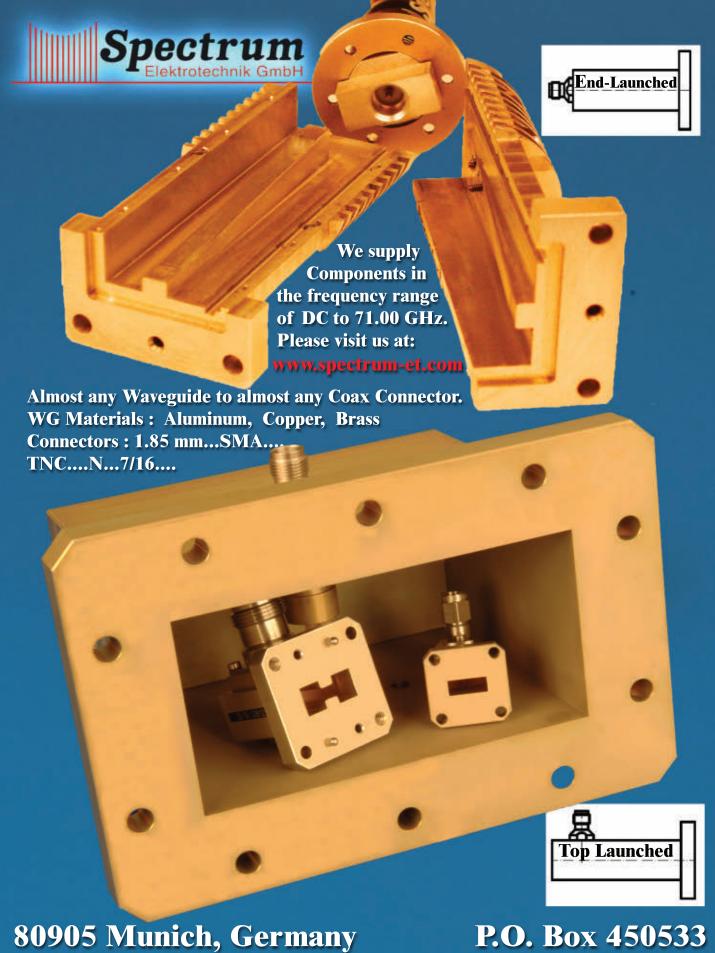
* Coupling Value: 3, 6, 8, 10, 13, 16, 20 dB.



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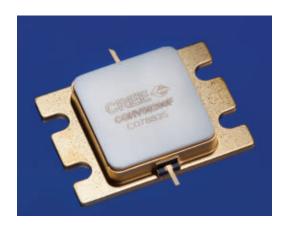
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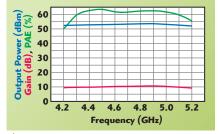
C-Band GaN HEMT Delivers 200 W CW

Cree Inc.
Research Triangle Park, N.C.

roposcatter, satellite ground stations, and beyond-line-of-sight communication require high power — hundreds of watts to kilowatts — to overcome the high loss and variable propagation inherent in longrange microwave links. These C-Band applications have historically used traveling wave tube amplifiers (TWTA) or klystron power amplifiers to achieve the required power.

With the introduction of Cree's new 200 W GaN HEMT, solid-state power amplifiers (SSPA) can replace TWTAs and klystrons for such applications while offering greatly improved performance. Previously, SSPAs combined a large number of lower power devices. Now, with a 200 W device, the SSPAs can be

smaller and lighter, reduce hardware and operating costs and improve system reliability.



A Fig. 1 Pulsed performance of the GaN PA with a 43 dBm, 100 μs, 10 percent duty cycle input drive.

PRODUCT DESCRIPTION AND PERFORMANCE

The CGHV50200F is a 50 ohm GaN HEMT, internally matched at both input and output. The device was designed for high output power, efficiency and gain across a wide band-

width. From 4.4 to 5 GHz, it provides over 200 W output at 48 percent power-added efficiency (PAE) and 15 dB small-signal gain. At 180 W output, the device can drive a load VSWR of 3:1 at all phase angles without damage.

The transistor is supplied in a ceramic metal-flange package (type 440215) with a flange size of 17.4×24 mm, not including the gate and drain leads. The surface area can dissipate $166~\mathrm{W}$ at a maximum case temperature of $85^{\circ}\mathrm{C}$. With $48~\mathrm{percent}$ PAE, power consumption and heat dissipation are reduced, simplifying the electrical and mechanical design of high power SSPAs.

In a demonstration amplifier circuit, the device delivers 198 to 218 W (53 to 53.4 dBm) CW output power from 4.4 to 5 GHz, with 47 to 49 percent PAE and 11.4 to 11.8 dB power gain. Small-signal gain is 14.9 to 15.1 dB. *Figure 1* shows the pulsed performance of the device.

Figure 2 demonstrates the effectiveness of the input and output matching, with $|S_{11}|$ ranging from -4 to -12 dB and $|S_{22}|$ from -9 to -14 dB. **Figure 3** shows the two-tone linearity versus output power with 1 MHz spacing of the test carriers. Third-order intermodulation distortion (IMD) is less than 22 dBc up to

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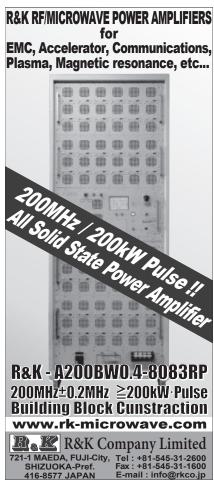
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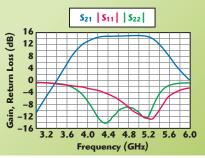
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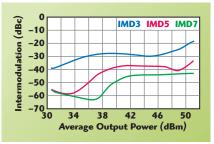
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ProductFeature



▲ Fig. 2 Input and output return loss, showing the quality of the internal matching.



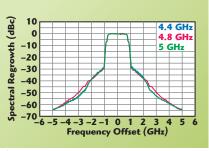
▲ Fig. 3 Two-tone intermodulation distortion with 1 MHz test signal spacing at 4.4 GHz.

100 W output, with fifth- and seventhorder IMD at progressively lower levels, which is expected for a transistor amplifier. With OQPSK modula-

tion, linearity at 48 dBm output power is specified as -34 dBc at the middle of the frequency band. *Figure 4* shows the OQPSK spectral mask at several frequencies.

The amplifier's typical drain bias is +40 V. The 125 V maximum drainsource voltage provides ample margin for peak voltages resulting from operating class, matching and modulation. The gate threshold voltage is typically -3 V, with the gate bias ranging from -2 to -3.5 V, depending on the desired class of operation.

A demonstration board (CGHV50200F-TB) is available and enables easy evaluation of the device in a proven circuit. The



▲ Fig. 4 OQPSK spectral mask at 4.4, 4.8 and 5 GHz with the PA backed off to 48 dBm output power.

board includes input and output connectors and transmission lines, DC blocking capacitors, decoupling stubs for drain and gate bias, bypass capacitors and a power connector. The printed circuit board is layered with a heat spreader that can be mounted on a cold plate or attached to a heat sink.

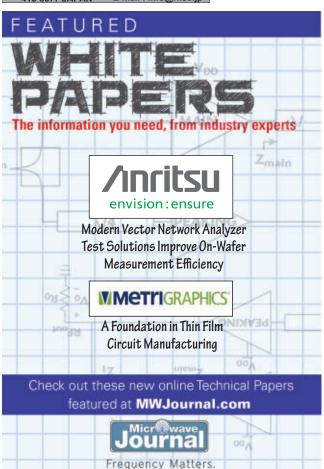
TARGETED APPLICATIONS

The main application for the CGHV50200F is tropospheric scattering or troposcatter. At C-Band, radio propagation is normally limited to line-of-sight. Ionized layers of the atmosphere do not efficiently reflect microwaves, and the short wavelengths are not refracted by the topographic features that allow lower frequency signals to reach beyond the horizon. Despite these limitations and depending upon weather phenomena, a small amount of C-Band energy will bend and scatter and pass beyond the horizon. Using the brute force of hundreds or thousands of watts, reliable communication can be achieved at distances much greater than a typical microwave path.

Satellite communication is the other major C-Band application that requires significant transmitter power. Higher power amplifiers enable smaller antennas at the earth station and increase the reliability of the link.

A high power transistor such as the CGHV50200F allows designers to build SSPAs with fewer devices, which greatly simplifies power combining, device gain matching and DC power distribution. The device also has the linearity for OQPSK modulation when operated "backed off" at 100 W average output power.

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TechBriefs



16 kHz to > 67 GHz Ultra-Broadband Ceramic Capacitors

assive Plus Inc. (PPI) has introduced the 01005BB104 and 0201BB104 ultra-broadband 100 nF multilayer ceramic capacitors. With a case measuring $16 \times 8 \times 8$ 8 mils, the 01005BB104 is the industry's smallest 100 nF broadband part characterized for RF performance, according to Passive Plus. The capacitor has resonant-free DC blocking and RF coupling from 16 kHz, at the lower 3 dB frequency, to beyond 67 GHz. On suitable substrates, insertion loss is less than 1 dB, and return loss is better than -15 dB. The 01005BB104 is rated at a DC working voltage (WVDC) of 4 V and is available in a nickel-tin termination.

The 0201BB104 also provides resonant-free DC blocking and RF coupling from 16 kHz to beyond 65 GHz, with less than 1.3 dB insertion loss and better than -15 dB return loss on suitable substrates. Up to 40 GHz, the insertion loss is typically under 0.6 dB and return loss better than -20 dB. The 0201BB104 is rated at a WVDC of 16 V and measures $24 \times 12 \times 12$ mils. It is available in nickel-tin and gold terminations.

All lots of the 01005BB104 and 0201BB104 are tested at RF frequencies to insure performance consistency. Modelithics offers RF models for

both types, enabling accurate design simulation on various substrates and with a range of mounting pad dimensions. Modelithics models are offered with free 30-day trials.

Passive Plus offers a wide variety of ultra-high-Q, broadband, and general-purpose multi-layer ceramic capacitors for commercial and military applications.

VENDORVIEW
Passive Plus Inc.
Huntington, N.Y.
www.passiveplus.com



Integrated RF Switching and Microprocessor in One Device

he EtherChip™ EC459™ is the world's first device integrating RF switching and a full-featured microprocessor on a single device, according to Ethertronics.

Embedded in the EC459 are Ethertronics' proprietary algorithm, and communication and control conduits that enable Active Steering.™ The EC459 samples and switches among various antenna radiation patterns, adaptively choosing the best one. Combining the device with an advanced Ethertronics antenna architecture, Ethertronics provides OEMs with an easy-to-integrate, plug-and-play solution. This frees an OEM's existing operating system or apps pro-

cessor, since the EC459 handles this for them. No baseband software or hardware modifications are required for product integration.

Active Steering maximizes throughput and reliability in 3G and 4G (LTE and LTE-Advanced), reduces interference, enables seamless hand-off between cell towers, and provides connection reliability and spectral efficiency. Active Steering demonstrated a 30 percent improvement in spectral efficiency during recent trials on two Tier One LTE carrier networks in the United States and Europe.

The EC459 operates from 100 to 6000 MHz, supporting the

GSM/W-CDMA/LTE, Wi-Fi, Bluetooth, RFID and GPS bands. The device features a flexible control interface that is customizable among SPI, I2C, UART and USART protocols, providing flexibility and speeding integration and testing. The EC459 is packaged in a $4 \times 4 \times 0.65$ mm³ QFN.

Worldwide application support and user development tools are available, including an evaluation board, antenna reference design, host firmware driver and PC control software with driver.

Ethertronics Inc.
San Diego, Calif.
www.ethertronics.com





2015 PLENARY SPEAKER

SOFT ASSEMBLIES OF RADIOS, SENSORS AND CIRCUITS FOR THE SKIN

- Dr. John Rogers

Swanlund Chair, Professor of Materials Science and Engineering, Professor of Chemistry University of Illinois, Urbana-Champaign



Professor John A. Rogers obtained BA and BS degrees in chemistry and in physics from the University of Texas, Austin, in 1989. From MIT, he received SM degrees in physics and in chemistry in 1992 and the PhD degree in physical chemistry in 1995. From 1995 to 1997, Rogers was a Junior Fellow in the Harvard University Society of Fellows. He joined Bell Laboratories as a Member of Technical Staff in the Condensed Matter Physics Research Department in 1997, and served as Director of this department from the end of 2000 to 2002.

He is currently Swanlund Chair Professor at the University of Illinois at Urbana/Champaign, with a primary appointment in the Department of Materials Science and Engineering, and joint appointments in several other departments, including Chemistry. He is Director of the Seitz Materials Research Laboratory.

Rogers' research includes fundamental and applied aspects of materials for unusual electronic and photonic devices, with an emphasis on bio-integrated and bio-inspired systems. He has published more than 450 papers and is inventor on over 80 patents, more than 50 of which are licensed or in active use. Rogers is a Fellow of the IEEE, APS, MRS and the AAAS, and he is a member of the National Academy of Engineering and the American Academy of Arts and Sciences. His research has been recognized with many awards, including a MacArthur Fellowship in 2009, the Lemelson-MIT Prize in 2011, the MRS Mid-Career Researcher Award and the Robert Henry Thurston Award (American Society of Mechanical Engineers) in 2013, and the 2013 Smithsonian Award for Ingenuity in the Physical Sciences.



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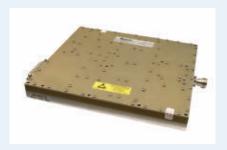








TechBriefs



600 W, X-Band Solid-State Power Amplifier

omtech PST's solid-state power amplifier (PA) module delivers 600 W peak output from 8.5 to 10 GHz with 58 dB nominal power gain. Designed for radar applications, the BMC858109-600 PA handles pulse widths from 300 ns to 100 µs at duty cycles up to 10 percent and less than 1 dB pulse droop. Typical rise and fall times are under 60 ns. Input VSWR is better than 1.5:1 and output VSWR is less than 2:1.

The amplifier design uses GaN devices in an AB configuration to achieve high efficiency and low harmonics. DC to RF efficiency is 20 percent and harmonic levels are better than

-40 dBc for the second, and -50 dBc for the third. The PA operates from a single 40 V supply and nominally draws 7.5 A with a 10 percent duty cycle signal. The operating temperature range is 0° to 55°C, measured at the base plate of the unit.

The design incorporates detectors that sample forward output and reflected output signals. The output samples are 50 dB below the forward and reflected signals. The PA has built-in protection that prevents exceeding the maximum pulse width, duty factor, temperature and load VSWR. The RF input connector is SMA, while the output features a

Type TNC. The unit weighs 4 lbs. and measures $8.8"\times 8.0"\times 0.5".$

The amplifier features a digital interface for monitoring status. It also provides an option for controlling gain and phase, which enables the PA to be integrated into higher power radar systems using conventional binary or phased array combining. This capability supports power levels up to 16 kW.

Comtech PST Corp. Melville, N.Y. (631) 777-8900 www.comtechpst.com



0.5 to 40 GHz High-Speed Tuner Captures 500 MHz Bandwidth

he P540B500 wideband tuner from diminuSys spans 500 MHz to 40 GHz with 500 MHz instantaneous bandwidth, fast tuning, low phase noise, control flexibility, output versatility and surprising affordability. Overall tuner gain is adjustable from -20 to +40 dB.

The P540B500 design enables input preselection with bypass, and input preamplification, bypass, or attenuation. The tuner's wideband output is centered at either 1000 or 1200 MHz, with auxiliary outputs at 900, 120/160 and 21.4 MHz included. All four ports are synchronous and without frequency inversion. Control is by a simple command set via the includ-

ed Ethernet, serial or USB interfaces.

With its enhanced performance option, the system tunes in 1 Hz increments and can switch between any two frequencies in less than 100 µs. Phase noise at 10 kHz offset is below -105 dBc/Hz when tuned to 40 GHz and well below that for lower frequencies. The P540B500 includes an external frequency synthesizer input to accommodate a user-provided local oscillator. The tuner can change bands, preselection, gain and attenuation in less than 100 ns in this mode, which is tailored to ELINT, SIGINT and COMINT applications.

The P540B500 resides in a low profile 1U rack-mount chassis with

custom configurations available. A field replaceable 2.92 mm input connector is standard. Air cooling input and output ports are both on the rear panel. The system operates from 85 to 264 V AC and 47 to 63 Hz. Availability is 30 to 60 days; price for the standard system is \$42,500.

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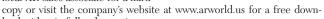
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CatalogUpdate

EMC & RF Testing Catalog VENDORVIEW

AR has completed another version of their full line product catalog. Many new products have been added and various sections have been updated to help make your equipment research more efficient. The new "find it fast" charts and color coding provide more in-depth product information, guiding you to the specific RF & EMC testing products you need faster. Please contact your local AR sales associate for a hard copy or vicit the compony's websit



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AR RF/Microwave Instrumentation

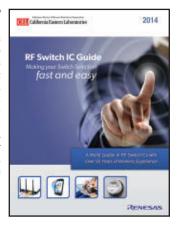
www.arworld.us



California Eastern Laboratories (CEL) product selector guide for Renesas RF Switch ICs helps make your switch selection fast and easy. CEL offers a broad selection of RF switch ICs with many configurations, package styles, performance and price points. This selector guide is a great aid in helping to simplify your selection of the best and most economical RF switch ICs for your application.

RF Switch IC Guide

California Eastern Laboratories (CEL) www.cel.com/rf



4G Functional and RF Design Validation

VENDORVIEW

The new brochure for Keysight's E7515A UXM wireless test set presents a highly integrated signaling test set created for functional and RF design validation in the 4G era and beyond. The UXM provides the capabilities you need to test the newest UE and chipset designs, delivering LTE-Advanced (LTE-A) category 4/6/7 now and handling more complex requirements later. Its powerful



and extensible architecture supports multiple cells, carrier aggregation, MIMO, internal fading and a built-in application server, allowing you to assess design readiness with greater confidence.

Keysight Technologies Inc. www.keysight.com

Rapid PCB Prototyping Catalog

The LPKF Laser & Electronics In-House Rapid PCB Prototyping Catalog features not only the milling and laser systems the manufacturer has become known for, but also its complete line of throughhole, multilayer and SMT/finishing equipment. LPKF is the only company to provide the full line of equipment necessary to complete in-house PCB prototypes up to eight layers in-house. To learn more about LPKF's in-house PCB prototyping technology, visit the company's website.

LPKF Laser & Electronics www.lpkfusa.com



RF Product Guide VENDORVIEW

Pasternack's latest 264 page catalog contains thousands of in-stock products such as RF cable assemblies, an expanded portfolio of RF amplifiers, 60 GHz systems and modules, and hundreds of other passive and active RF components, all available for same-day shipping worldwide. Pasternack also introduced 24/7 support to assist customers all over the world to place orders, request quotes and answer questions. Other improved features include an updated adapter and cable assem-



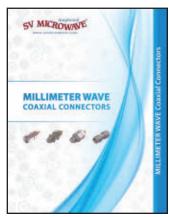
bly matrix that allows users to easily identify all available in-series and between-series configurations. Visit the company's website to request a free print copy or to download a PDF version.

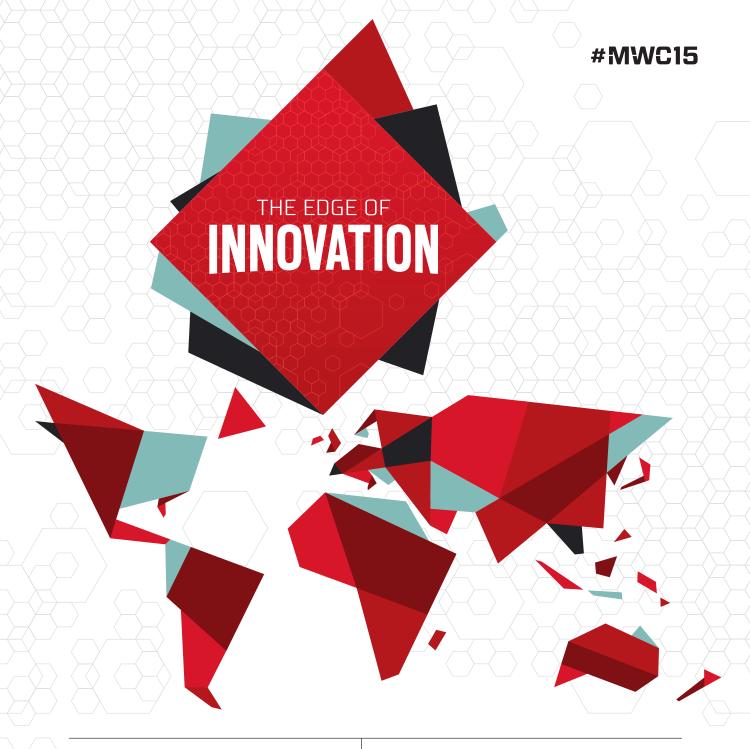
Pasternack Énterprises www.pasternack.com

Millimeter Wave Connector Series

SV Microwave recently released a new catalog for their Millimeter Wave connector series. SV's product line offers the precision, quality and performance needed for the millimeter wave spectrum through 67 GHz. Products include 2.92, 2.4 and 1.85 mm and are available as connectors, terminations, attenuators, cable assemblies and customized solutions. Visit www.svmicrowave.com/productliterature or email marketing@svmicro.com for your copy.

SV Microwave www.svmicrowave.com







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The mobile communications revolution is driving the world's major technology breakthroughs. From wearable devices to connected cars and homes, mobile technology is at the heart of worldwide innovation. As an industry, we are connecting billions of men and women to the transformative power of the Internet and mobilising every device that we use in our daily lives. The 2015 GSMA Mobile World Congress will convene industry leaders, visionaries and innovators to explore the trends that will shape mobile in the years ahead. We'll see you in Barcelona at **The Edge of Innovation.**

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Components

Ultra Wideband Cavity Notch Filter



3H Communication Systems announced the LTE/WiMAX, an ultra wideband cavity notch filter. This 2600 MHz notch filter provides >50 dB rejection across

the notch bandwidth of 190 MHz, while maintaining low insertion loss of < 0.5 dB from DC to 2210 and 2900 to 3500 MHz. Contact sales@3hcomm.com for additional information.

3H Communication Systems www.3hcomm.com

Ultra Broadband PIN Diode Switches



Ducommun RF Product Group released a new line of ultra-broadband PIN diode switches. These ultra-broadband PIN diode switches cover 0.05 to 110

GHz. These unique, ultra wideband and high frequency switches are ideally suited for R&D laboratories, test environments and high frequency applications. Ducommun's ultra-broadband PIN diode switches are available both as reflective or absorptive, from SPST to SPST configuration.

Ducommun www.ducommun.com

PIN Diode Switched Filter Assembly



Model SF-69-BZ is a four-band with two through paths PIN diode switched filter assembly. It is capable of

isolations of 60 dB minimum in RFH-RFOUT and a 30 dB minimum in RFL-RFOUT. The amplitude flatness is 2 dB peak-to-peak. This device operates with a handling power of \pm 23 dBm CW RFH, \pm 18 dBm RFL, 1 W max via 6 bits of TTL compatible logic and a switching speed less than 300 nsec max. The package size is 3" \pm 2.25" \pm 0.70".

G.T. Microwave www.gtmicrowave.com

S-Band Circulator

The SZM 10497 is a small form factor, high power S-Band package drop-in circulator for



commercial markets. Derived from a military part capable of handling up to 4 kW peak power, the circulator is suited to GaN power amplifi-

ers for microwave heating, lighting and ATC radar applications. Operating from 2.4 to 2.5 GHz, the SZM 10497 offers an average power of 250 W max, peak power of 1000 W, return loss of 18 dB min and operating temperature of -20° to +80°C. **MESL Microwave**

MESL Microwave www.meslmicrowave.com

Four-Way, 0° Splitter/Combiner VENDORVIEW

Mini-Circuits' ZB4PD-282-50W+ high power, four-way, 0° splitter/combiner covers 500 to 2750 MHz, supporting applications such as

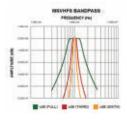


high band PCS, UNII, WiMAX and more. This model can handle up to 100 W RF input power as a splitter and is capable of passing up to 0.5 amps DC current from input to output. It

provides 1.5 dB insertion loss, 21 dB isolation between ports, 5° phase unbalance and 0.3 dB amplitude unbalance.

Mini-Circuits www.minicircuits.com

Switched-Capacitor Filter ICs



Mixed Signal Integration (MSI) announce d switched-capacitor filter ICs with frequencies of 5 MHz and beyond. The selectable very high fre-

quency filter ICs (MSVHFS1-6) have six pole Butterworth, Elliptic or Bessel lowpass responses or six pole full octave, one third octave or one sixth octave bandpass responses. These filter ICs have better roll-off and stopband rejection than passive component or low order op-amp solutions.

Mixed Signal Integration www.mix-sig.com

PIN Diode Digital Step Attenuators





Pasternack Enterprises Inc. released their new 5, 8 and 10 bit broadband PIN diode digital step attenuators with performance up to 40 GHz, depending on the

configuration. These programmable, variable step attenuators are commonly used in electronic warfare, military and space communication systems, radar, and test and measurement applications. Pasternack's new digital step attenuators come in 30 and 60 dB values and have attenuation step resolution of 0.25 to 1 dB depending on the model.

Pasternack Enterprises Inc. www.pasternack.com

8-Bit Digital Phase Shifter





PMI model no. PS-2G6G-8B-SFF is an 8-Bit digital phase shifter that operates from 2 to 6 GHz. This model offers 360 degrees of phase shift having a LSB of 1.4 degrees.

The insertion loss is 10.5 dB typical with a typical phase accuracy of ± 0.5 degrees. It is supplied in a housing measuring $3.25^{\shortparallel} \times 3.25^{\shortparallel} \times 0.94^{\shortparallel}$.

Planar Monolithics Industries Inc. www.pmi-rf.com

Converters

VENDORVIEW



Richardson RFPD Inc. announced the availability and full design support capabilities for three new converters from Analog Devices Inc. The new devices include a digital-to-ana-

log converter, an analog-to-digital converter and a dual analog-to-digital converter. All of the devices are suitable for a range of applications, including 3G/4G cellular infrastructure, aerospace, and defense and instrumentation.

Richardson RFPD www.richardsonrfpd.com

PIN Diode Switches



S2D Microwave Inc. offers broadband, high performance RF microwave PIN diode switches. S13: 16A5811 is high performance 8.4 to 10.2 GHz absorptive design with low insertion loss of 3 dB

max. The switch is phase and amplitude matched. **S2D Microwave Inc.** www.s2dmicrowave.com

Power Circulator

Model CT-1872-S is rated at $60~\mathrm{kW}$ peak and $600~\mathrm{W}$ average power at $325~\mathrm{MHz}$. The unit



provides 20 dB min. Isolation at 0.2 dB insertion loss and 1.20:1 max VSWR. The extremely compact design has flange to flange insertion length of only

 $6\frac{3}{4}$ " and a height of $5\frac{1}{4}$ ". For use in radar applications, it has $1\frac{5}{8}$ " EIA connectors. It is also available at other UHF frequencies and connector types.

UTE Microwave www.utemicrowave.com

Cables and Connectors

Low PIM TerminationsVENDOR**VIEW**



MECA Electronics announced its latest low PIM terminations with -165 dBc (typical) passive intermodulation. All of MECA's low PIM

terminations cover 698 to 2700 MHz. These terminations are ideal for IDAS/ODAS, inbuilding, base station, wireless infrastructure, 4G and AWS applications. VSWR is 1.10:1 (typ-



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To support an even wider range of applications, Mini-Circuits tiny surface-mount transformers and baluns now cover frequencies up to 18 GHz! Our latest designs achieve consistent performance across very wide frequency bands, and our baluns have demonstrated great utility for chipsets. With over 250 trusted models in stock representing a wide selection of circuit topologies and impedance ratios, chances are, we have a solution for your needs!

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MECA Electronics Inc. www.e-MECA.com

SMP/SMPM Style Line of Connectors



SV Microwave released a new SMP/SMPM style line of connectors-QuarterBack® series. The line utilizes a quarter turn bayonet style

coupling nut with a locking feature for standard SMP/SMPM interfaces. The QuarterBack® connectors are ideal for high vibration and test applications that require a large number of mating cycles. Email marketing@svmicrowave.com for more information.

SV Microwave www.svmicrowave.com

Amplifiers

Solid State AmplifierVENDOR**VIEW**



AR's new 3000S1G2z5 solid-state amplifier provides 3000 W of output power from 1 to 2.5 GHz. It offers superior gain flatness, exceptional noise figure, better

efficiency and harmonics than current TWTA models and the reliability of solid state. Typical applications include radiated immunity testing and TWT replacements.

AR RF/Microwave Instrumentation www.arworld.us

Traveling Wave Tube Amplifiers



dB Control introduced new Ka-Band high power traveling wave tube amplifiers. Model number dB-3860 offers

700 W peak, 34.5 to 35.5 GHz and indoor rack-mount. Ka-Band applications include radars, test and measurement, antenna pattern, radar cross-section measurements and EW simulation.

dB Control www.dbcontrol.com

RF Amplifiers



Fairview Microwave debuted new off-theshelf RF amplifiers which operate to 26.5 GHz. This release includes power amplifiers, broadband amplifiers, gain blocks, limit-

ing amplifiers and low noise amplifiers designed for use across the spectrum of commercial and defense applications. Gain levels reach 50 dB, P1dB from 10 mW to 20 W, noise figure from 0.8 to 2 dB and gain flatness of ± 0.5 dB. All amplifiers are in-stock and ship same-day.

Fairview Microwave www.fairviewmicrowave.com

Amplifier and Lensed Horn

The AS0104-700/300 dual band solid state amplifier, used in automotive EMC testing, complements the company's existing 1 to 4 GHz amplifiers. It is designed to exceed the



requirements of the automotive radar pulse test standards when used in conjunction with the new MILME-GA lensed horn, enabling ease of calibration using CW power.

Each band covers only one octave (1 to 2 and 2 to 4 GHz), and the lowest test frequencies are 1.2 and 2.7 GHz in each band.

MILMEGA Ltd. www.milmega.co.uk

Low Noise Amplifier



top broadband low noise amplifier operating from 0.5 to 40 GHz. The amplifier exhibits 42 dB small-signal gain and averages 6 dB noise figure over the entire frequency range.



The minimum P-1 dB is $+10\,$ dBm. The benchtop amplifier is designed to use 100 to 240 V AC power directly

from a lab outlet. The bench top amplifier measures 3.75° (W) \times 4.15° (L) and 1.75° (H). It is equipped with K female connectors for RF input and output.

SAGE Millimeter Inc. www.sagemillimeter.com



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NewProducts

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The TA79ZSD6 is a new X-Band, 100 W solid-state GaN power amplifier. It uses a compact and light-weight 17.4 × 24

 \times 4.1 mm package. It has greater than 36 percent drain efficiency and 11 dB of gain. It requires a +30 V supply voltage. All bias, input and output matching circuitry are included.

Tokyo Keiki

www.tokyokeiki-usa.com

Microwave Power Amplifier

The AHP2225-38-3330 is a three-stage PHEMT MMIC based power amplifier module $\frac{1}{2}$



offering 33 dB of linear gain and 30 dBm minimum output power at 1 dB gain compression over 18 to 26.5 GHz, with excellent gain flatness and VSWR. The

amplifier has built-in DC voltage regulators and voltage inverters and requires only a single +9 to 12~V DC power supply.

Wenteq Microwave Corp. www.wenteq.com

Sources

Surface Mount OCXO



Morion announced its new high precision, surface mount OCXO for SatCom, GPS, network-synchronization and test & measurement applications. The

MV272M is presently available at a fixed frequency of 10 MHz. The MV272M has phase noise of -115 dBc/Hz at 1 Hz offset, with short-term stability (ADEV) better than 5×10^{-13} per second. The surface mount (SMD) package measures $30\times 41\times 17$ mm and is RoHs compliant.

Morion US LLC www.morion-us.com

Signal Synthesizers



The SC800 nano-Synth™ is a fully integrated broadband CW signal synthesizer designed with a proprie-

tary architecture in a rugged and miniature $2" \times 1"$ surface mountable package. The output frequency range is 25 MHz to 6 GHz with average output power of +10 dBm. Tuning at 1 Hz resolution, the multiple PLL design eliminates close-in phase spurs associated with fractional-N PLLs. The SC800 has low phase noise of -118 dBc/Hz at 10 kHz offset from a 1 GHz carrier. SignalCore Inc.

www.signalcore.com

Miniature Footprint I2S PLL Synthesizer



The KFXLNS-1000 is an ultra-low noise frequency source operating at a fundamental output frequency of 1000 MHz from a 100 MHz external reference signal. This prod-

uct operates with a 12 V supply and offers significant phase noise and spectral quality over competing and more complicated multiplied-up legacy solutions. It is the perfect clean signal source for minimizing overall system noise and reduced power consumption. The typical phase noise is -120 dBc/Hz at 100 Hz offset, -140 dBc/Hz at 10 KHz and -174 dBc/Hz at 1 MHz offset. Synergy Microwave Corp.

www.synergymwave.com

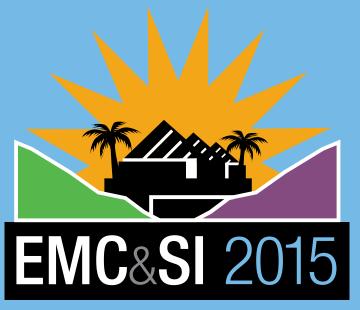
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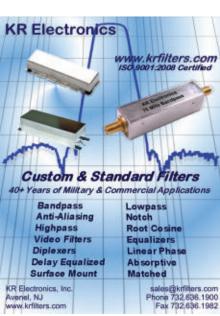
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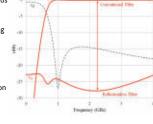


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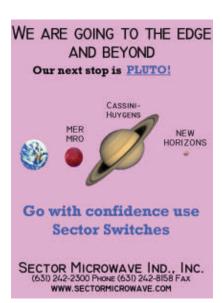
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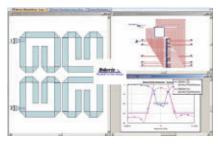




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Narda Safety Test Solutions www.narda-sts.com

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OML introduced a new option for its signal generator frequency extension module.

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www.onlinc.com

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BookEnd



Highly **Integrated Low Power Radars**

Sergio Saponara, Maria Greco, Egidio Ragonese, Giuseppe Palmisano and Bruno Neri

ontinuing advances in semiconductor technology, from RF to signal processing, are enabling radar to migrate from defense to civilian applications. Automotive is probably the most obvious example, with radar being used to assist drivers and increase safety through applications such as autonomous cruise control, blind spot detection and parking aids. Not as well known, perhaps, are harbor traffic control and contactless vital sign monitoring (heart and breath rate, for example).

The authors claim that radar is superior to competing sensor technologies, such as laser, lidar, ultrasound, and visible and infrared cameras. Radar operates in all weather conditions and provides detailed information about the target: whether a target exists, its distance, speed, and direction of arrival. Since the radiation is non-ionizing, radar is safe for biomedical applications.

Seeing the market opportunities and the underlying technology enablers, the premise of "Highly Integrated Low Power Radars" is that a radar sensor designed to minimize size, power consumption and cost will become a ubiquitous, contactless sensor for a myriad of applications. The book aims to walk through the design trade-offs and technology options to show the reader how to achieve this goal.

The book covers both theory and practical applications, beginning with scenarios and requirements for highly integrated, low power radars. To gain wide commercial adoption, the radar design should trade performance to reduce cost, size and power consumption. Integrating all functions using system-on-a-chip (SoC) or system-ina-package (SiP) approaches is the strategy to achieve this. Technology and integration options for the transceiver and antenna are discussed, including comparisons of GaAs, CMOS and SiGe technologies.

Chapter 3 addresses the hardware and software platforms for the digital signal processing of the radar waveform. The authors compare the computational capabilities of various graphics processors, field programmable gate arrays (FPGA) and digital signal processors (DSP).

The remainder of the book addresses applications, with one chapter devoted to health-care signal processing and one to automotive. Two case studies are presented, covering front ends developed for healthcare and harbor surveillance. The final chapter on applications describes IC designs for 24 GHz short-range and 77 GHz long-range automotive radar systems.

"Highly Integrated Low Power Radars" offers a topical view of the emerging commercial applications for radar. It should be interesting and informative for anyone interested in the applications or enabling technologies.

To order this book, contact:

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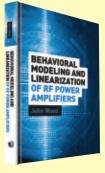


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This is the first article in our new "Fabs and Labs" series featuring companies with interesting design, fabrication, assembly and test facilities that we visit in our travels around the industry.



ercury Systems has hit the sweet spot for producing commercial and defense sensor systems in their Advanced Microelectronics Centers. Mercury is a provider of commercially developed, open sensor and Big Data processing systems, software and services for critical commercial, defense and intelligence applications. They are able to deliver innovative solutions, rapid time-to-value and world-class service and support to prime contractor customers due to their intelligent setup of design and manufacturing facilities and industry expertise.

About six years ago, Mercury targeted additions in the RF and microwave sector that would enable them to provide the entire sensor chain from end-to-end: acquire, digitize, process, store, exploit and disseminate/electronic countermeasures. They acquired several microwave companies including LNX, KOR Electronics, Micronetics and Echotek Corp. These acquisitions gave them a wide array of microwave component and sub-assembly capabilities to fill out their portfolio of sensor capabilities.

After these acquisitions, Mercury developed their Advanced Microelectronics Centers in Hudson, N.H. and West Caldwell, N.J. to design and build high quality sensor assemblies. These centers provide the right flexibility and volume needed for the high performance sensor market. While many larger companies provide high volume production, they typically lack the flexibility needed by customers. There are also many smaller companies that provide flexibility but lack the scale to provide LRIP and production quantities. With their Advanced Microelectronics Centers, Mercury

has filled the missing gap with facilities that can be flexible and still meet the production volumes needed for this market.

The Hudson facility has 72,000 square feet with 12,000 square feet of clean room space and the West Caldwell facility has 23,000 square feet with 8,000 square feet of clean room space. The clean rooms provide full manual and automated microelectronics assembly plus digital and high frequency testing. The facilities also have machine shops and environmental testing facilities so that everything can be done on-site to build prototype and production products. Design and manufacturing engineers are co-located in the facilities for a smooth handoff from development to production. The clean rooms are also laid out to maximize cleanliness and optimize workflow. Both facilities have the same equipment and processes so that there is capacity flexibility and redundancy. For critical military programs, these attributes can be a strategic advantage. The New England locations are also in close vicinity to many of their customers.

Mercury Systems has built a "right-sized" company that is flexible like a small company but also has the scale to provide production quantities of high-performance sensor systems, including microwave components and sub-assemblies. They are leveraging their microwave company acquisitions and combined design power to introduce custom products to the commercial and defense industries. View their Advanced Microelectronics Center overview video at

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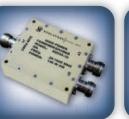
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Low Insertion Loss Model D9048



Directional Couplers Operate, at Rated Power, into High Load VSWR Conditions.



Combiners are Fully Isolated and Designed to Handle Severe Input Unbalances.

High Power Combiners/Dividers

Model	Type	Frequency (MHz)	Power (W CW)	Insertion Loss (dB)	VSWR	Phase Balance (°)	Isolation (dB)	Size (L x W x H) (Inches)	
D6233	2-Way	10-1000	25	0.75	1.35	5	20	3.25 x 2 x 1.1	
D8632	2-Way	20-1000	50	0.7	1.40	5	20	2.2 x 1.5 x 0.9	
D8300*	2-Way	20-1000	100	0.5	1.35	5	20	2.45 x 2 x 0.91	
D8544W	2-Way	20-1000	100	0.5	1.35	3	18	2.85 x 2.5 x 1	
D8682	2-Way	20-1000	500	0.7	1.35	5	15	5.2 x 2.65 x 1.8	
D9264	2-Way	20-1000	1000	0.8	1.40	5	18	6.5 x 6.25 x 2.25	
D7365	4-Way	20-1000	100	0.75	1.35	5	20	5.09 x 2.3 x 1	
D7439	4-Way	20-1000	250	0.75	1.35	5	18	5.1 x 5 x 1.5	
D9048	4-Way	20-1000	500	0.6	1.35	5	17	5 x 4.7 x 1.4	
D9075	4-Way	20-1000	1000	0.65	1.35	5	15	5.7 x 4.7 x 1.75	

^{*} Designed for 10 W / Input Non-Coherent.

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			High	Power Di	rectional Cou			
Model	Coupling (dB)	Туре	Frequency (MHz)	Power (W CW)	Insertion Loss (dB)	VSWR (ML)	Directivity (dB)	Size (L x W x H) (Inches)
C9770	30	Dual	20-1000	50	0.7	1.10	20	3 x 2 x 1
C9191	30	Dual	20-1000	100	0.7	1.25	20	1.76 x 1.16 x 0.57
C9552	30	Dual	20-1000	150	0.8	1.30	20	3 x 2 x 1
C8696	40	Dual	20-1000	150	0.35	1.25	20	1.76 x 1.16 x 0.57
C8858	40	Dual	10-1000	250	0.4	1.30	20	2.01 x 1.16 x 0.57
C9446	40	Dual	20-1000	250	0.5	1.30	20	3 x 2 x 1
C8686	50	Dual	20-1000	500	0.35	1.25	20	5.2 x 2.68 x 1.69
C9107	53	Dual	20-1000	1000	0.4	1.30	20	4.45 x 2.4 x 1.59

All designs provide full port-to-port Isolation.