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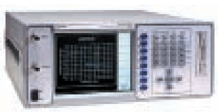
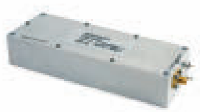


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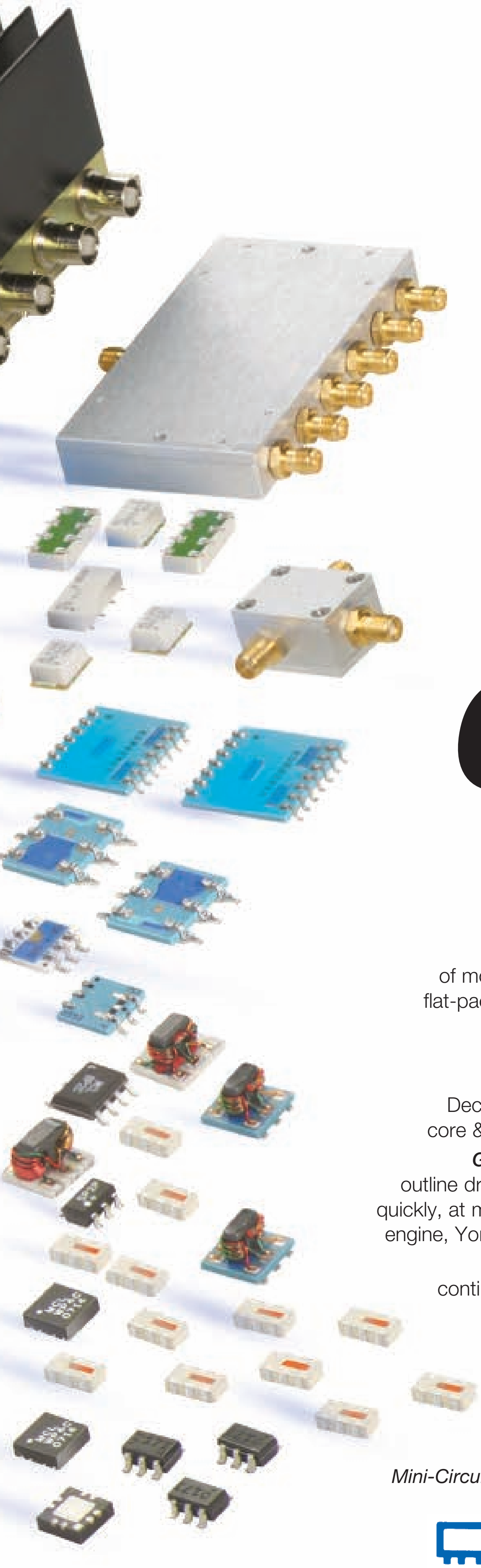

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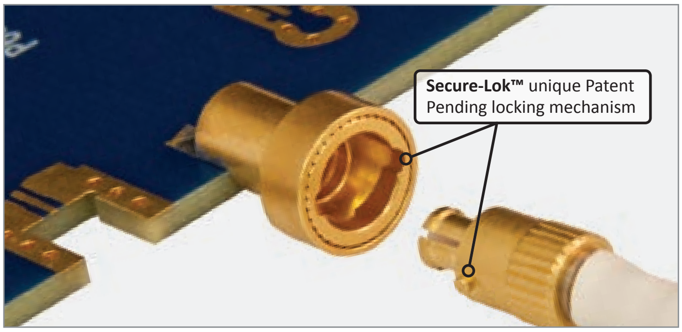

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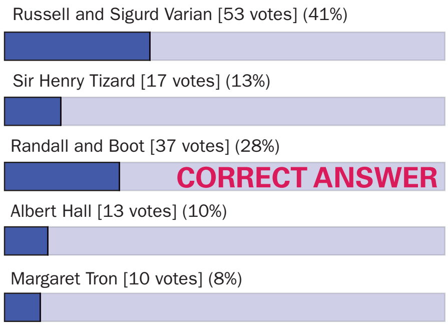
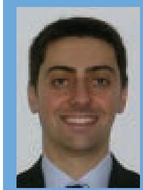


Paolo Galbiati, PLM director of SIAE MICROELETTRONICA, outlines how the company, which specializes in point-to-point microwave radio systems, developed from humble beginnings in Milan in the 1950s to become a global player in the 21st century. Find this interview online at www.mwjournal.com/Galbiati.

Executive Interviews



Mauro Marchetti, co-founder and CEO of Anteverta Microwave, explains the company's spin-off from Delft University and its collaboration with Maury Microwave. Find this interview online at www.mwjournal.com/Marchetti.

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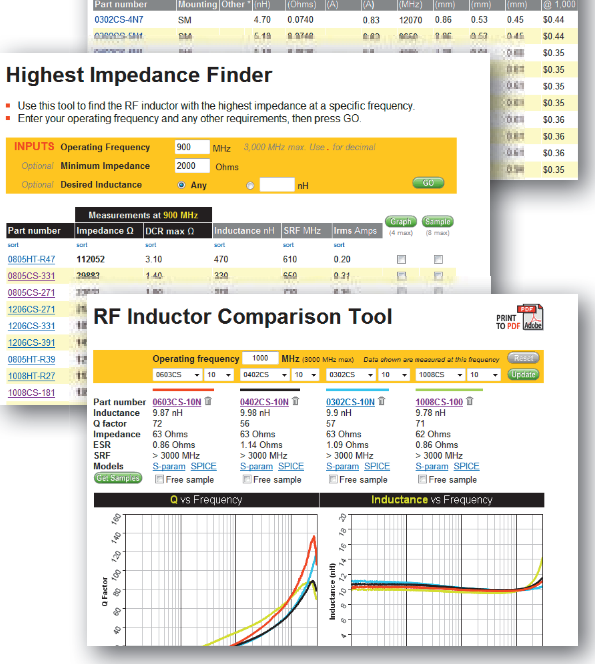

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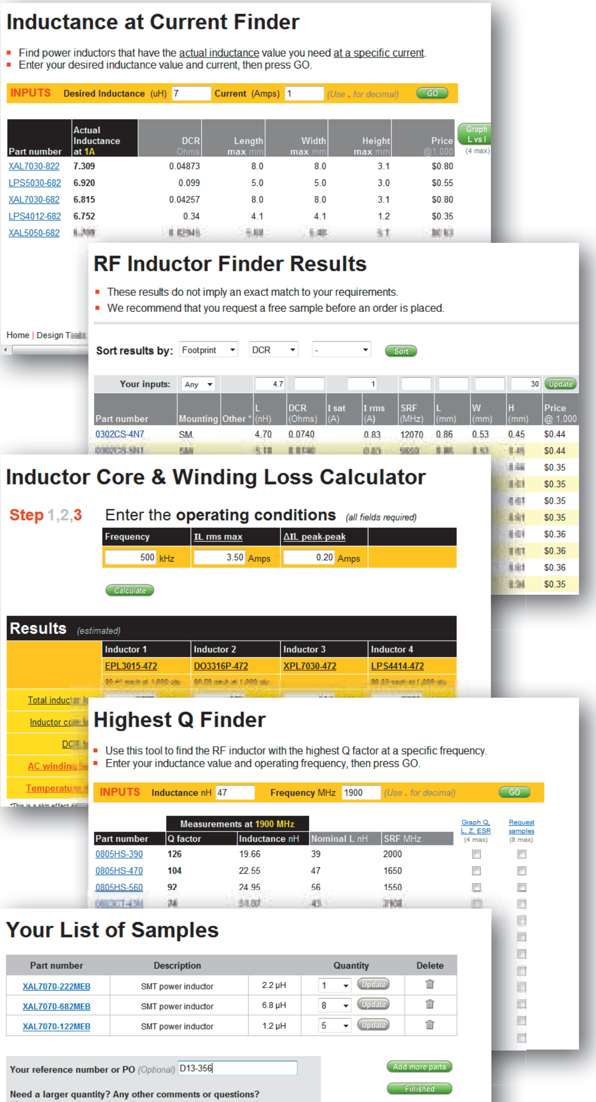

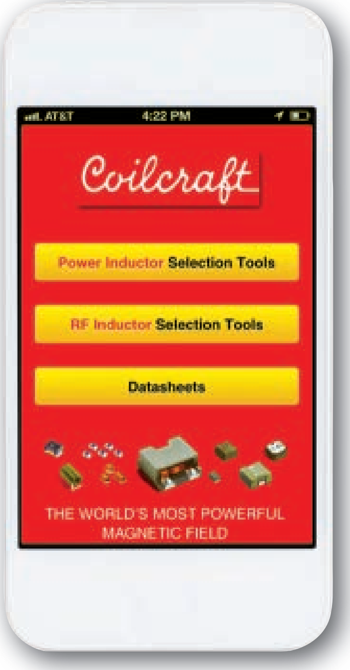

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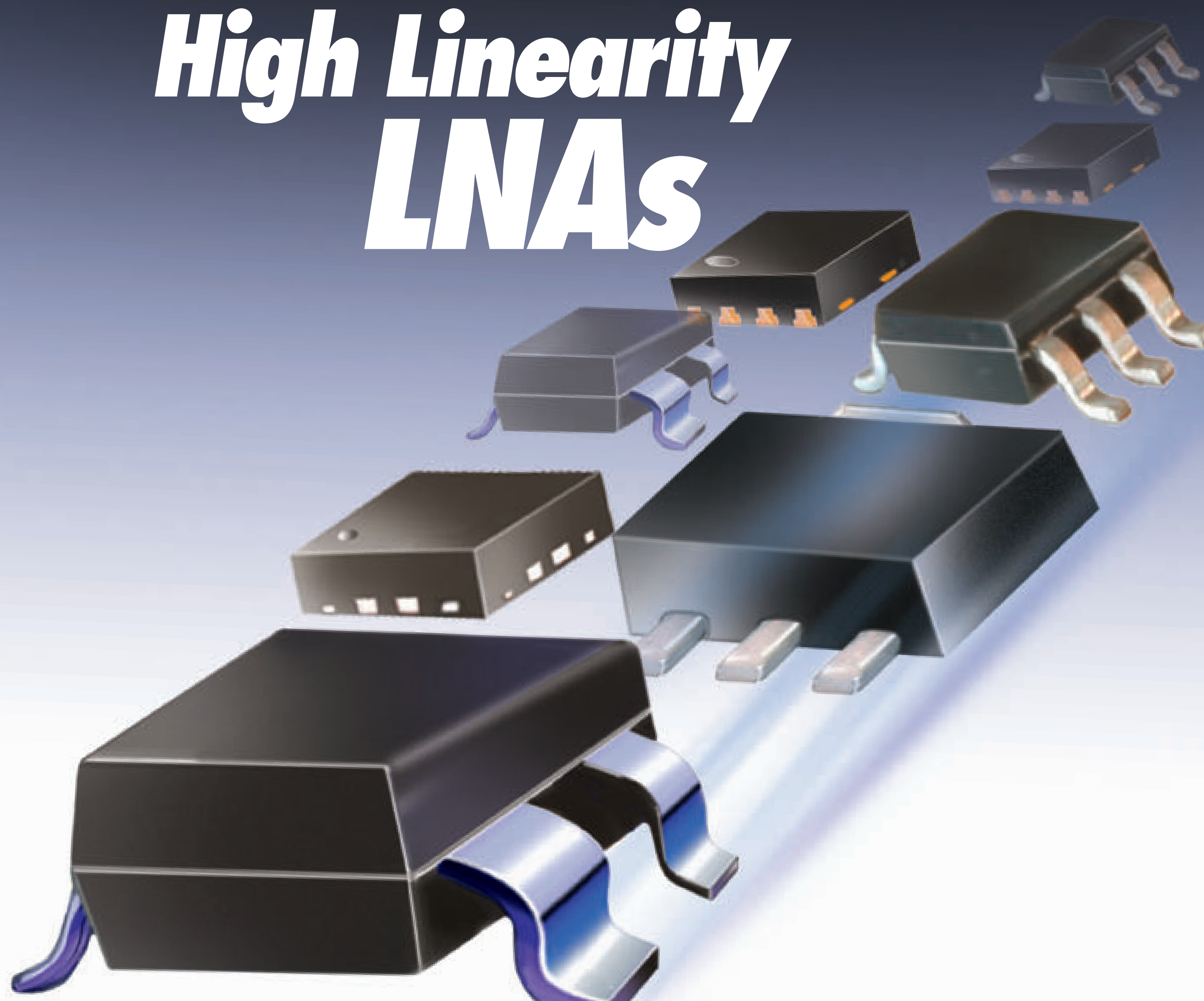

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PMA-545G3+	700-1000	31.3	0.9	33	22	158	4.95
PMA-5454+	50-6000	13.5	0.9	28	15	20	1.49

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PMA-5453+	50-6000	14.3	0.7	37	20	60	1.49
PSA-5453+	50-4000	14.7	1.0	37	19	60	1.49
PMA-5456+	50-6000	14.4	0.8	36	22	60	1.49
PMA-545+	50-6000	14.2	0.8	36	20	80	1.49
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27	28	29	30	31	1	2
3	4	5	6 **Webinar:** **GPS Interference: Jamming Effects** Sponsored by ROHDE & SCHWARZ	7 **Webinar:** **Antenna Design Automation** Sponsored by Agilent Technologies	8	9
10	11	12 **Webinar:** **Radar Systems** Sponsored by ROHDE & SCHWARZ	13	14	15 ARFTG **Call for Papers Deadline**	16
17 EUROPEAN MICROWAVE WEEK NCC NUREMBERG, GERMANY 6-11 OCTOBER 2013 www.eumweek.com MEET EXPERTS MAKE FRIENDS **Call for Papers Deadline**	18	19 **Webinar:** **MIMO Radar: Demystified** ROHDE & SCHWARZ	20	21 **Webinar:** **EW Testing** Sponsored by Agilent Technologies	22	23
24	25	26	27 **Webinar:** **RF/uW Cable Test** Sponsored by Agilent Technologies	28	1	2

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February 18–21: NATE 2013, February 18-21, Fort Worth, Texas

February 25–28: MOBILE WORLD CONGRESS, Barcelona | 25 - 28 February 2013

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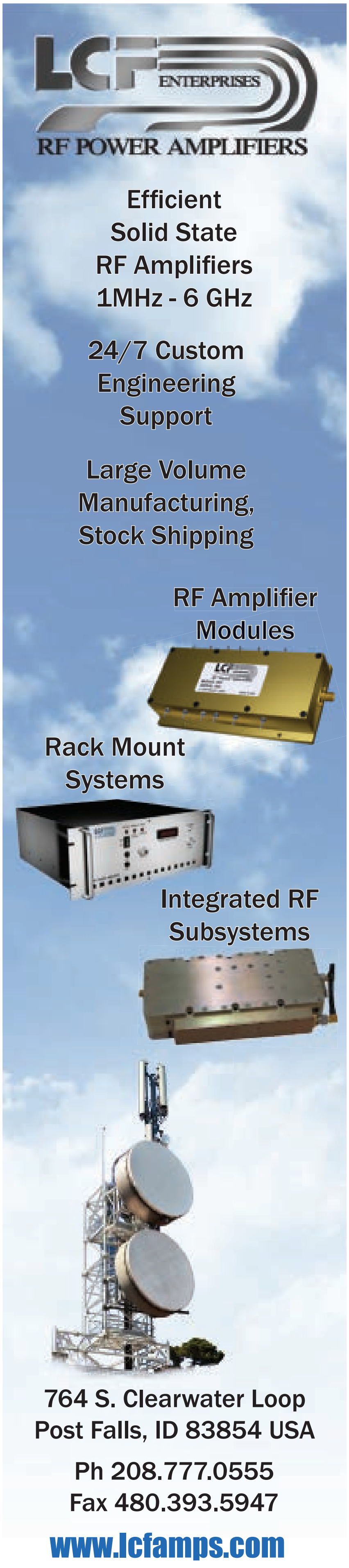

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IEEE International Solid-State Circuits Conference
February 17–21, 2013 • San Francisco, CA
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February 18–21, 2013 • Fort Worth, TX
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MARCH

ISQED 2013
International Symposium on Quality Electronic Design
March 4–6, 2013 • Santa Clara, CA
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March 24–28, 2013 • Monterey, CA
http://aces.ee.olemiss.edu/conference/2013

PSATS 2013
5th International Conference on Personal Satellite Services
March 28–29, 2013 • Toulouse, France
www.psats.eu

APRIL

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www.wamicon.org

Microwave & RF 2013
April 10–11, 2013 • Paris, France
www.microwave-rf.com

IWS 2013
IEEE International Wireless Symposium
April 13–18, 2013 • Beijing, China
www.iws-ieee.org

SPACOMM 2013
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April 22–26, 2013 • Venice, Italy
www.iaria.org/conferences2013

MAY

CTIA WIRELESS 2013
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NCMMW 2013
National Conference on Microwave and Millimeter Wave

MWIE 2013
Microwave Industry Exhibition
May 21–24, 2013 • Chongqing, China
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IMS 2013
IEEE MTT-S International Microwave Symposium
June 2–7, 2013 • Seattle, WA
www.ims2013.org

81st ARFTG Microwave Measurement Symposium
June 7, 2013 • Seattle, WA
www.arftg.org

AUGUST

EMC 2013
August 5–9, 2013 • Denver, CO
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Since you're reading this, it appears that the Mayan prediction of the end of the world was not realized. The Maya civilization may not have predicted the apocalypse, but we can credit them with developing the only known fully developed written language of the pre-Columbian Americas. While their choice of substrates on which they delivered those writings was limited to an early form of crude paper and monuments, the options for information delivery today are vast and varied.

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I'm proud to be able to say that our print publication has served the industry for 55 years, and it's still going strong. In fact, it's the platform most preferred by our subscribers. For those subscribers who prefer to read the issue online, our digital edition offers all of the bells and whistles that you would expect from that format. The print format lends itself to the longer, in-depth technical material found within its pages, and we are fortunate to be able to provide more content than any other publication serving our industry, thanks to our loyal readers, advertisers and authors. Within the pages of this issue you'll find lots of unique content, including a cover feature written by industry icon Eli Brookner. The editorial staff has compiled a great lineup of articles for 2013, so stay tuned.

We launched our new website last year and I hope that it has been a useful resource for you. One of the popular new features on the site is the presence of Channels, which aggregate content on specific market sectors and technologies. If you haven't checked out the Channels, I encourage you to do so. Mwjournal.com is also the place to find a treasure trove of archived material, including white papers, webinars and back issue articles. In addition, it hosts the Buyer's Guide directory of more than 1000 companies. The site also integrates the social media platforms LinkedIn, Twitter, Facebook and Pinterest.

Our RF and Microwave Community on LinkedIn is an active, informative resource boasting nearly 15,000 members. It acts as a discussion forum and job posting board and is a great place to interact with colleagues. Several members of the MWJ team post frequently on Twitter as well, spreading the word about articles of particular interest and timely industry events. They welcome all followers.

I hope that you're taking advantage of our newsletters. We broadcast two each week: the Flash and the Advisor. The Microwave Flash provides the latest news, events, industry analysis and resources. The Microwave Advisor delivers the latest product offerings from leading manufacturers. We also produce the monthly Military Microwaves newsletter, which features insight from industry experts that you won't find anywhere else, along with the latest news, products and events. You can update your newsletter choices and profile at any time on our website to ensure that you receive only the information that interests you.

I mentioned the launch of our mobile app earlier. It's now available on iTunes for iPhones and iPads, Google Play for Android-based phones and tablets, and Amazon for the Kindle. The app is free and provides the current issue, archived issues, an industry news feed, blog postings and executive interview feeds.

We launched *Microwave Journal China* last year to extend our reach to that growing market. This year, I'm excited to announce the debut of the Electronic Design Innovation Conference (EDI CON), to take place on March 12-14 in Beijing. This event combines a technical conference with an exhibition that includes many of the leading companies in our industry. The conference will be a combination of technical papers, workshops and panel sessions intended to deliver practical information on RF, microwave and high speed design to the working engineer. If your work takes you to China, I hope you'll join us.

Regardless of how you've found your way to our pages and regardless of which substrate you're utilizing, I'm glad that *Microwave Journal* brings value to your work and I appreciate your continued support.

On behalf of all of us at *Microwave Journal*, I wish all of our readers a happy, healthy and prosperous new year.

Regards,
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MIMO Radar: Demystified

MIMO radar is best for search not for track. When an array is used to search a large scan angle, it is best for maximum search energy efficiency to use subarrays of the array as the elements of the MIMO array to form what we call a subarray-MIMO or SA-MIMO. When searching out a small scan angle, the subarrays should be sized so that the volume of space illuminated by the subarrays of the subarray-MIMO array matches, or is smaller than, the volume of space to be searched. Using subarray-MIMO reduces the computation throughput. Monostatic MIMO does not provide an order of magnitude better rms angle resolution and accuracy, it is only at best a factor of $1/\sqrt{2}$ better (29 percent) for a monostatic MIMO system. Thinned conventional arrays can resolve about the same number of targets and provide approximately the same resolution and angle accuracy as thinned MIMO arrays.

The Multiple Input and Multiple Output (MIMO) radar has been built up as a technique that provides one or more orders of magnitude with better resolution and accuracy than conventional arrays. This is only because they have been doing an apples and oranges comparison. When doing an apples and apples comparison, the angle accuracy advantage is typically only a small amount better, approximately 29 percent. A 29 percent reduction in the angle accuracy can be realized, for example, when a linear array of N elements, or subarrays, is used as a monostatic MIMO array rather than a monostatic conventional array. Alternately, a monostatic MIMO array radar can offer the advantage of the same accuracy as a conventional array radar with a small aperture size, one that is $1/\sqrt{2} = 0.707$ smaller, or equivalently 29 percent smaller.

The advantage of a possibly smaller antenna would be important where the antenna size is a driving factor. This advantage of better angle accuracy or smaller antenna size for a monostatic array of N elements comes at the need for $\geq N$ times as much pulse compression match filtering and beamforming as needed for a conventional array. This large number of pulse compression comes about for two reasons. First, N orthogonal waveforms are transmitted simultaneously for the MIMO system requiring N matched filters per receive array element. Second, orthogonal or diverse[1,2] waveforms are usually Doppler intolerant and hence require a bank of matched filters, let us assume a factor F more, to cover the Doppler band of the received signals of one orthogonal or diverse waveform. When the matched filters are Doppler variant then we will need FN times more beamforming as well as pulse compression. In contrast, for conventional radar, only one matched filter is needed at the output of each receiver beamformer output. Furthermore, if a chirp waveform were used, as is often done, we have Doppler tolerance for the matched filters

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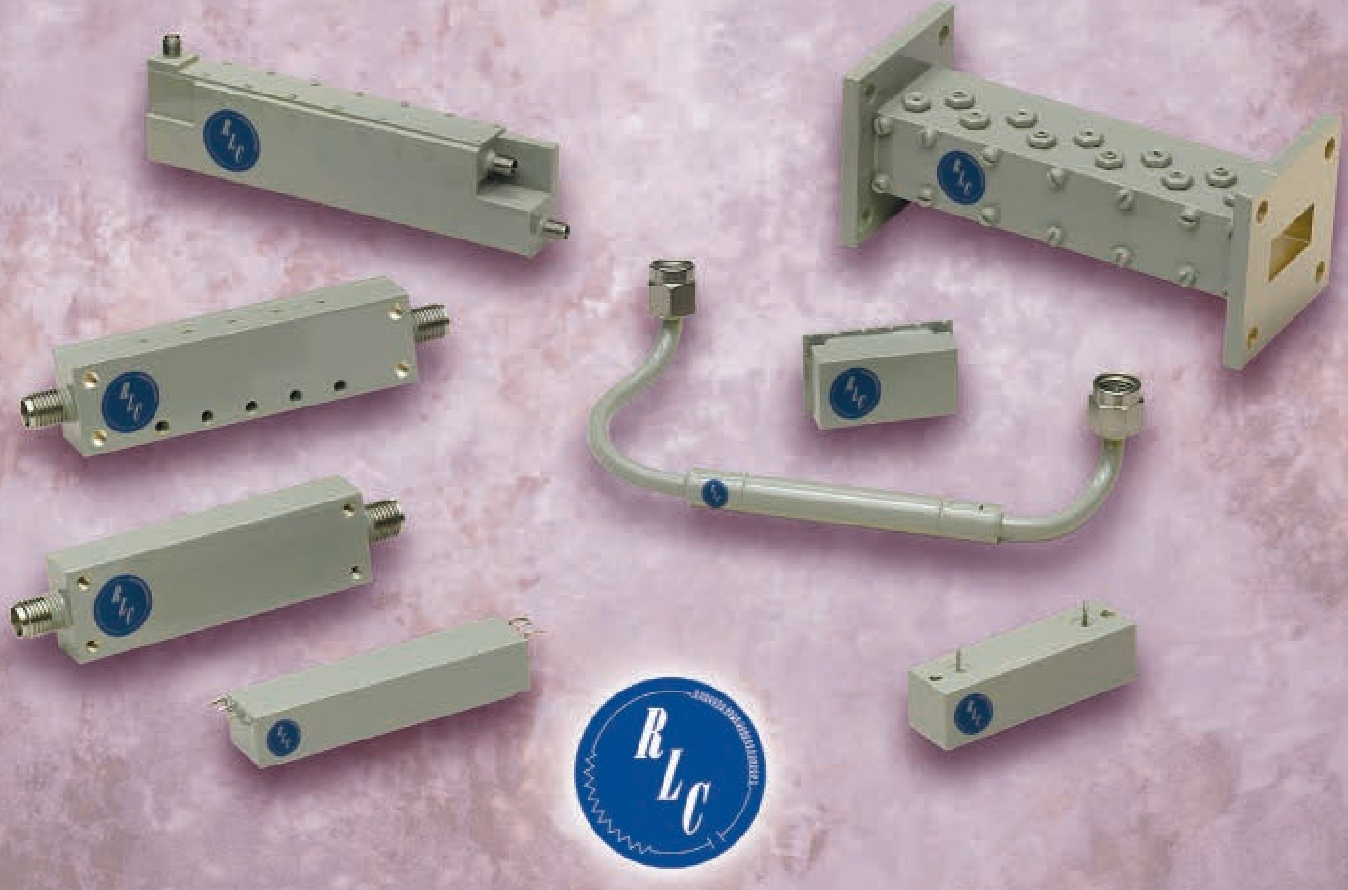

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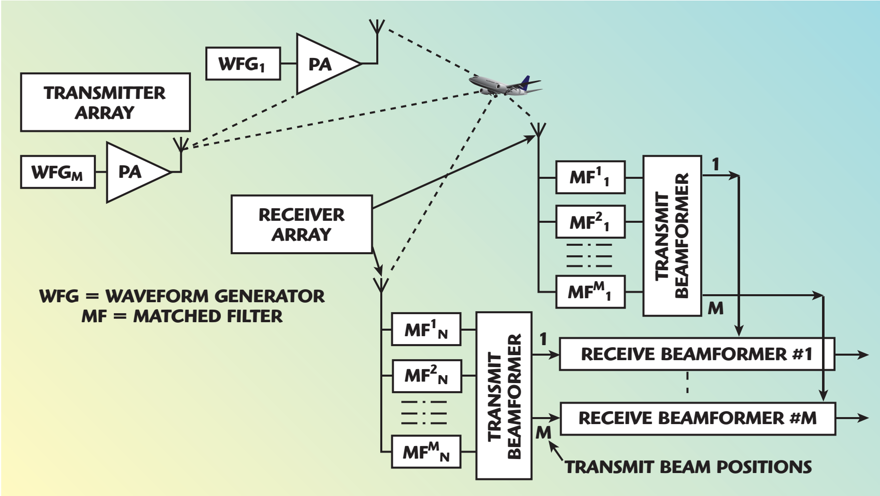
and only one matched filter is needed for the whole band of Doppler shifted chirp waveforms instead of a bank of F of them.

MIMO is not generally efficient for track, only for search. It is not efficient for track because, typically, it illuminates a large volume of space, when one only wants to illuminate the target. Even with search, care must be taken not to illuminate a volume larger than the volume to be searched. For a given array, ideally, it should be used as a MIMO array when doing search and as a conventional array when doing track. Consider a monostatic non-thinned array used for transmit and receive. As a MIMO array doing search, it will provide approximately 29 percent better rms accuracy of the detected targets location than a conventional array. For track, to get maximum SNR and minimize the energy used for track, the array should be used as a conventional array, with its beam focused using the whole array, unless doing track-while-scan.

Generally it would not be efficient to use the individual elements of an array as the MIMO elements, even if we wanted to search out nearly the whole volume illuminated by a single element. This is because typically a single element has a power gain pattern versus scan angle θ given by $\cos^n\theta$ where the ideality factor $n \approx 1.0$ to 1.5. Thus to search targets at the $\theta = 60°$ for $n = 1.5$ we would be at the same time radiating $1/(\cos^{1.5}60°)^2 = 8$ times the energy needed to search out the target at boresite or $\theta = 0°$. This is not efficient. We would have to radiate the energy needed to detect the target at 60° and radiate excess energy at angles for which $\theta \leq 60°$. What we would like to do is vary the energy used with scan angle. This can be done by not using the individual elements of the array to form the MIMO elements. Instead, we should use groups of elements of the array to form what we call subarrays. These subarrays can be made equal in size and they would all point in the same direction. By using subarrays as elements of the MIMO array, we are covering a more limited angle for a given coherent dwell. A number of dwells are used to search out the whole volume of space. As a result, we can adjust the energy radiated according to the amount needed for each dwell and be efficient



▲ *Fig. 1 Bistatic MIMO (after Frazer et al., Radarcon 2007, Boston, MA).*[2]

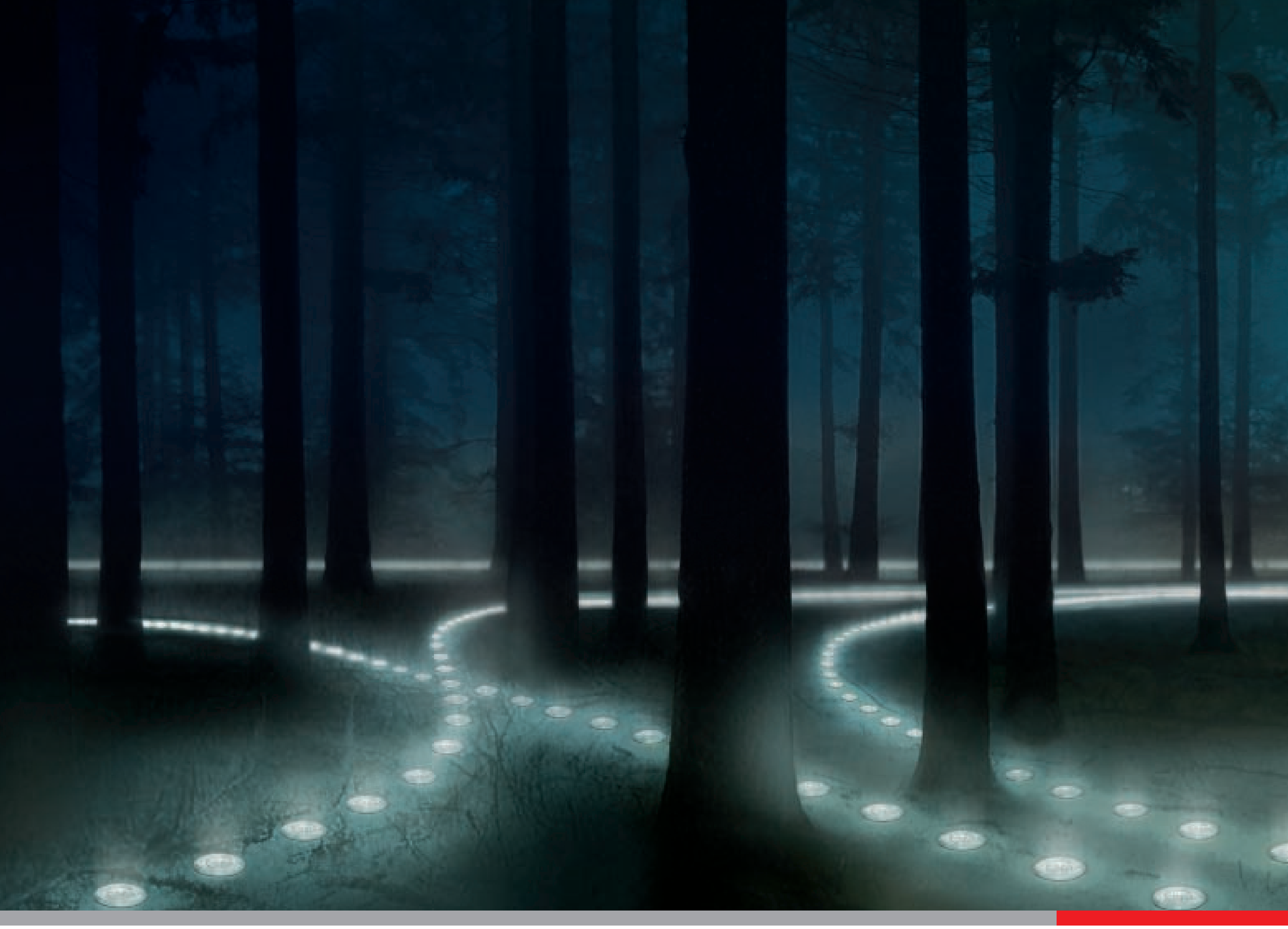
for search. If the volume of space to be searched is small, so that only one dwell is needed, then for maximum search efficiency, the subarray volume of space illuminated by the subarrays should be matched to the size of the region to be searched.

By way of example, if we wanted to generate a 120° wide horizon search fence that was only one beamwidth high in height, then the subarrays would have a vertical height that produces an elevation beamwidth equal to the horizon fence elevation beamwidth. The width of the subarrays would be a few element columns wide so as to cover only a small part of the 120°, like approximately 10° wide on boresight, so that the energy radiated for each subarray scan angle could be efficiently matched to the subarray scan angle. We will call a MIMO array formed using subarrays of the array elements a subarray-MIMO (SA-MIMO) array and one that uses the individual elements an element-MIMO (E-MIMO) array. For the above horizon fence, SA-MIMO array to search out a 120° horizon fence, the energy utilized is lower than if an E-MIMO was used. Not only is SA-MIMO search more efficient than an E-MIMO, it requires much less computation. With Q subarrays, the number of matched filters and beams to be processed is $(Q/N)^2$ lower. For $N = 100$ versus $Q = 10$, we have a factor of 100 fewer matched filters and beams. Hence the bottom line is that for an array:

1. For search, SA-MIMO processing should be used.
2. For track, conventional array processing should be used for maximum energy efficiency and to reduce the signal processing requirements.

If one could develop an element whose gain versus angle was constant over the search coverage angle and zero outside of this angle, then one could efficiently do search by use of the individual elements of the array for the MIMO array instead of subarrays. (This assumes the range is independent of scan angle). One way to possibly obtain such an element is to use a dome antenna.[3] Besides the question of realizability of such an element using the dome antenna, the dome antenna has its issues: it is bulky, has a polarization that varies with scan angle and has losses if implemented with a passive dome lens.

A very useful near term application for MIMO is the cohering of array faces of a multifaced array system (like the AEGIS or SPY-3 systems), or for cohering two identical radars in close proximity.[4-6] For the latter application, we get the increased sensitivity using existing radars without the need to develop a new radar. These two applications provide a 9 dB Power-Aperture-Gain (PAG) sensitivity advantage and 6 dB Power-Aperture (PA) search advantage, if coherent combining on transmit and receive is used. It is the one application for which MIMO can provide an order of magnitude improvement in angle accuracy. This results when the antennas for the two radars are slightly separated so that the phase centers for the two apertures result in an interferometric antenna pattern. Coherent combining can be applied to more than two radars. The combining can also be incoherent, thus not requiring coher-



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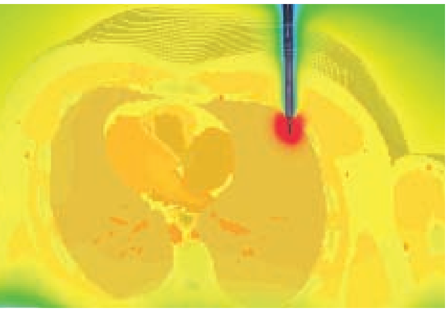

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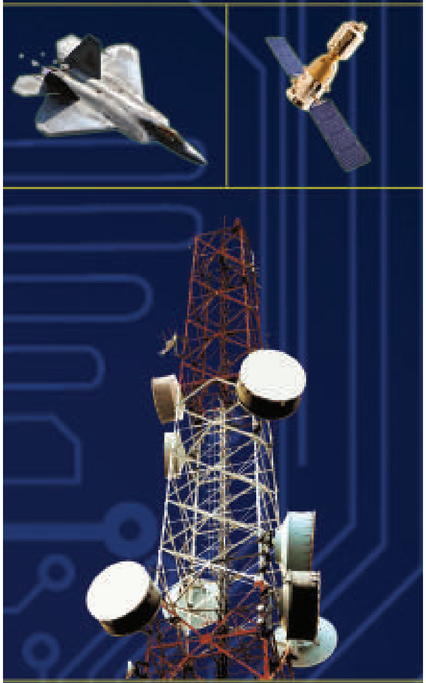

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ence on transmit.[7] Incoherent combining provides an 8.7 dB improvement for a Swerling 2 target.

MIMO has already been practically used for wireless communication systems, to provide increased data rate for a given bandwidth.[8,9] As the cost of signal processing gets lower, MIMO should find applications for radar systems in the future.

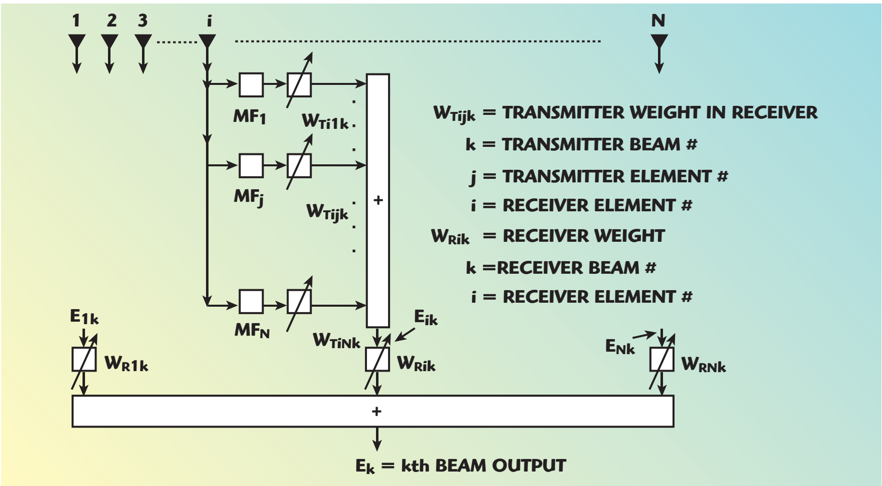
FIRST, WHAT IS A MIMO RADAR SYSTEM?

Consider a system consisting of linear transmit and receive antenna arrays of respectively M and N elements as shown in ***Figure 1*** for a bistatic system.[2] For a conventional radar system, all the radiating elements of the transmit antenna radiate the same waveform. Also, the antenna beams are typically focused on transmit and receive to form narrow beams at given scan angles. In contrast, for a MIMO system, generally each element of the transmit array radiates a different waveform with these waveforms often being orthogonal or diverse.[1,2] As a result, on transmit, the beam energy is not focused but instead illuminates the volume of space covered by one element of the MIMO array. The M orthogonal signals go out to the target and the M echoes are received by each of the N receiver antenna elements. Hence the name Multiple Input and Multiple Output (MIMO) system. Each receive element uses M matched filters to pulse compress each of the M echoes it receives from the target. For each receive element, the matched filter outputs are provided a phase shift that focuses the transmit beam on the target. Thus for a MIMO system, the transmit beamforming is done in the receiver. These M focused transmit beam outputs of each receive element that are focused on the target are now combined to form a receive beam pointing and focused on the target. The volume of space covered and to be searched by one MIMO element is covered by forming multiple such transmitted and received focused beams that cover the volume of space illuminated by each MIMO element. As discussed, the MIMO elements could be individual elements of the array or subarrays. It is important to point out that although the MIMO transmit beams are focused in the receiver, the power density on the target is 1/M times smaller for the MIMO array of M elements than for the conventional array of M elements. This is because although we focus the transmit beam on receive, on transmit the MIMO array energy is spread out over the MIMO element field-of-view which is M times that of the conventional array. ***Figure 2*** gives the detailed block diagram of a monostatic MIMO radar system.

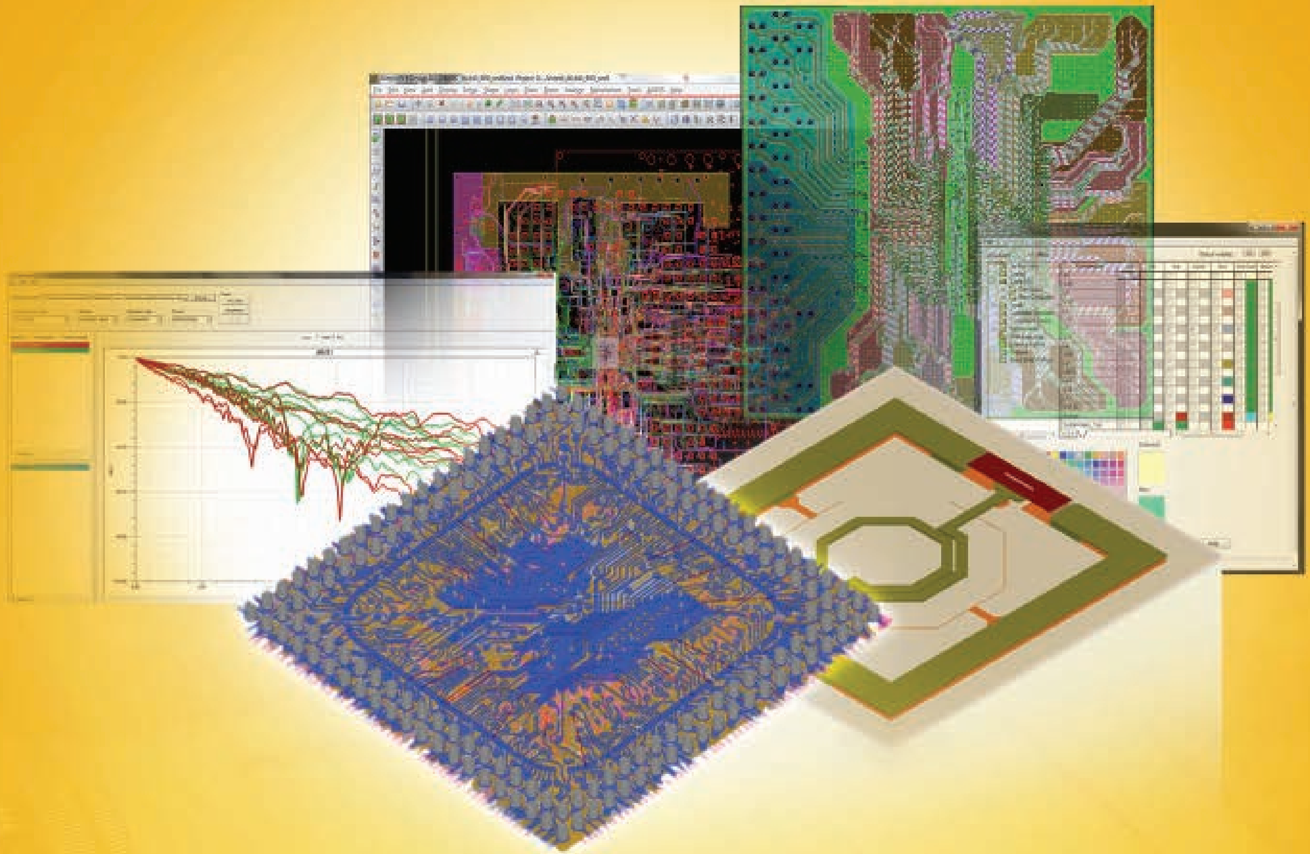
The purpose here is to provide a better understanding of MIMO radars and give an indication of where it is deemed useful. We will indicate where apples and oranges comparisons have been made. We will point out the issues with MIMO. Some of these issues have been pointed out before.[10-14] But one still sees a wrong comparison being made.[15]

RE BETTER ANGLE RESOLUTION AND ACCURACY

The claim is made that MIMO provides a resolution and angle accu-



▲ *Fig. 2 MIMO monostatic array receive beamformer.*



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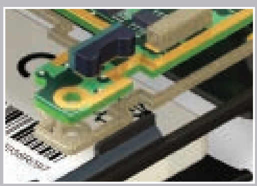
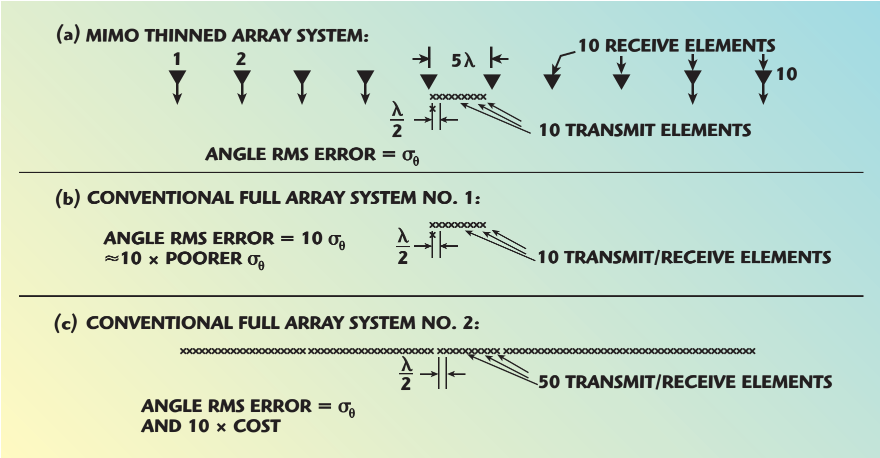
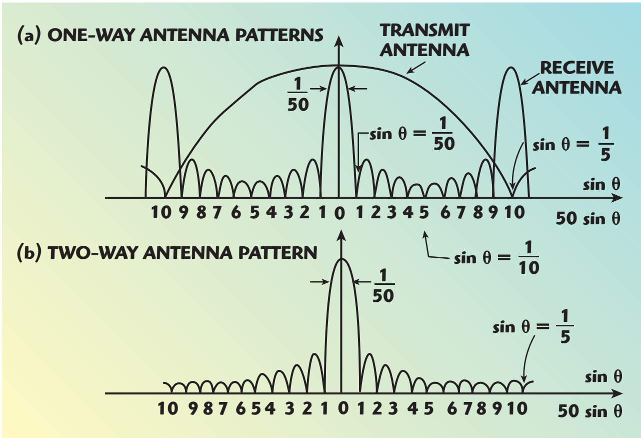




▲ *Fig. 3 MIMO vs. conventional monostatic radar systems.*

racy, orders of magnitude better than with conventional array radars.[1] This is because MIMO arrays which are thinned arrays can be used, with these being equivalent to full conventional arrays. Because the MIMO array is thinned, it can be longer and thus give better angle resolution and accuracy than a conventional array having the same number of elements, which they show to be a full array to avoid grating lobe. When this claim is made they are doing an apples to oranges comparison. For example, for the MIMO system, they would assume a receiver linear array (R) having 10 elements, with these elements 5λ apart, so that the array is 50λ long (see ***Figure 3***). The transmitter linear array (T) is assumed to be a linear array of 10 elements aligned along the same axis as the receive array, R, but with its elements λ/2 apart for a total length of 5λ (Figure 3a). The transmitting array could be located at the center of the receiving array as shown. This MIMO T/R array is equivalent to an array, called MIMO Virtual Array, obtained as the convolution of the transmit and receive antenna weightings.[1] Hence, for the assumption of a uniform weighting, for the T and R arrays the equivalent array is a full linear array having uniform weighting that is 50λ long (see Figure 3c).[1] As a result, we have a beamwidth of approximately λ/(50λ) = 1/50 radians and an angle accuracy that is a fraction of that, depending on the SNR. For the conventional array, to avoid grating lobes, they assume a non-thinned 10 element array having a λ/2 spacing, so its length is 5λ. This array is used for transmit and receive (see Figure 3b). Its beamwidth is λ/(5λ) or approximately 1/5 radians, ten times wider than for the MIMO array, so its beamwidth and accuracy are ten times worse. They also point out that to get the same resolution with a conventional array having no grating lobes, you would need an antenna consisting of 50 elements (see Figure 3c,) which would be approximately 50 times more expensive than the MIMO thinned array of Figure 3a. This is true, but they are making the wrong comparison. They should be using the same two T and R arrays for the conventional system as used for the MIMO system. The receive array will then have a main lobe and several grating lobes, but these grating lobes occur at the nulls of the transmitting array, if uniform illumination is being



▲ *Fig. 4 Conventional monostatic thinned array antenna patterns.*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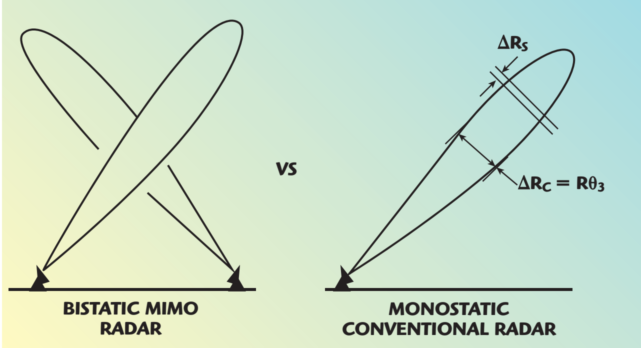
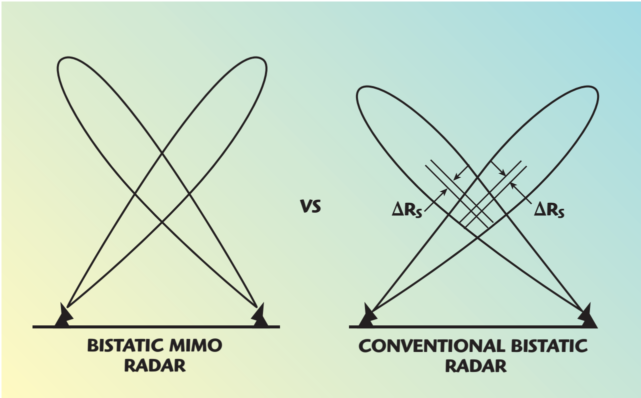
assumed as we are assuming here (see ***Figure 4a***). We are then left with a two-way pattern with just the main lobe, whose width is approximately 1/50 radians, which will give us an angle resolution and accuracy for the thinned conventional system that is about the same as for the MIMO array and it will not have grating lobes (see Figure 4b). So, in conclusion, we can get the same resolution and accuracy with an antenna system consisting of a conventional thinned receive array and full transmit array just as we can with an equivalent MIMO when an apples to apples comparison is being made. (Care needs to be used in forming the MIMO Virtual Array by the convolution of the thinned and full array weightings. Specifically the thinned array needs to have 50 what are called "dummy elements" at the λ/2 spacing between the active receive elements; see Appendix online at www.mwjournal.com/MIMOappendix.)

A second example, where they do an apples to oranges comparison, is the following. For the MIMO system, they assume two radars that are very widely spaced and compare it to the performance obtained when just one of these radars is used as a monostatic radar (see ***Figure 5***). For the widely spaced MIMO systems, one will get better detection, because of the angle diversity offered with the bistatic MIMO system and also much better target position accuracy than with the monostatic radar. Again this is the wrong comparison. They should be comparing the bistatic MIMO system with a conventional bistatic radar system having the same spacing between the radars. Then, one would be getting a position accuracy and detection performance about the same as for the MIMO system, because we realize the same angle diversity for the equivalent identical bistatic conventional system. ***Figure 6*** shows the advantage offered by the conventional bistatic radar system. Here, there are nearly orthogonal range measurements for the conventional radar. It is also possible to use the interferometric lobes, obtained by the coherent combining of the outputs of the two conventional bistatic radars, just as well as the MIMO system can. Though the interferometer lobes are very narrow for many geometries, there are then too many in one beam width. This is the case illustrated in ***Figure 7***. The interferometric lobes here are only 1 μr wide, which becomes 0.02 m at a range of 20 km. The number of the interferometric lobes in the main lobe beamwidth of 10 mr is approximately 10,000. It will be difficult to determine which interferometric lobe the target is located in, to make use of the fine accuracy offered by the interferometric lobes. This is true for both the conventional and MIMO bistatic radars.



▲ *Fig. 5 Bistatic MIMO vs. conventional monostatic system: Apples and oranges comparison.*



▲ *Fig. 6 Bistatic MIMO vs. bistatic conventional systems: Proper comparison.*

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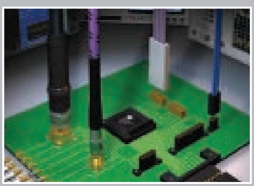

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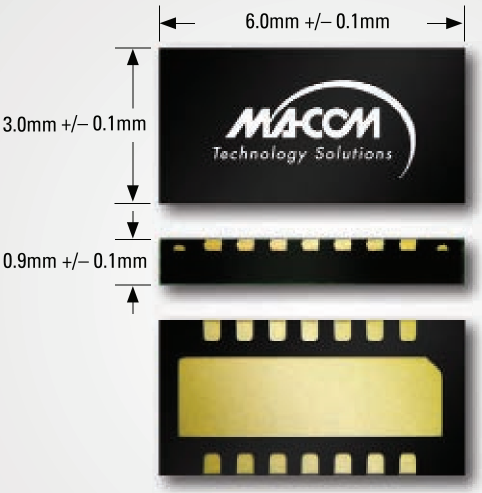

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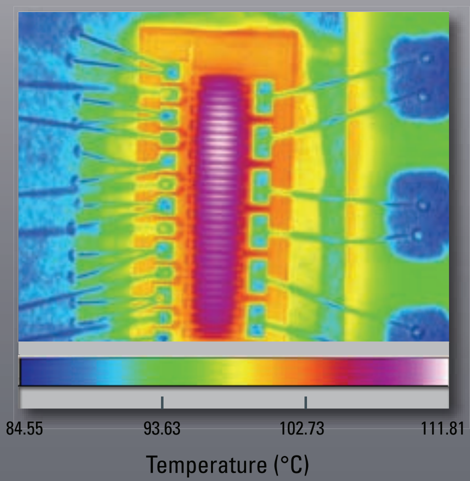

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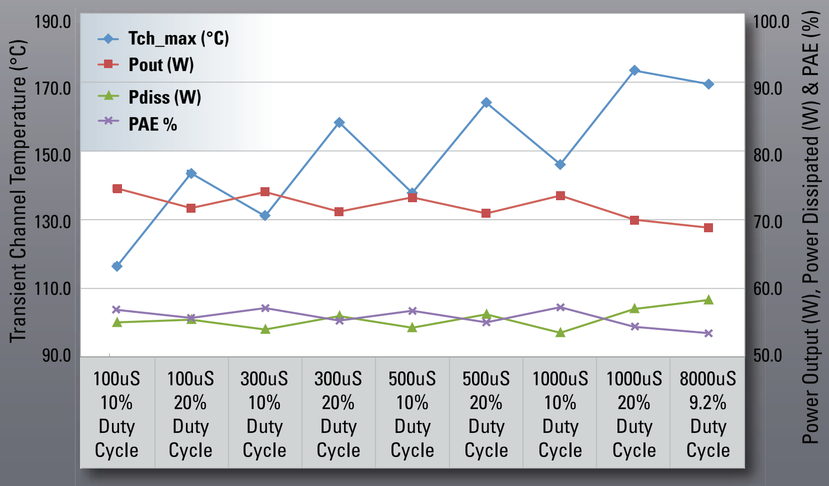

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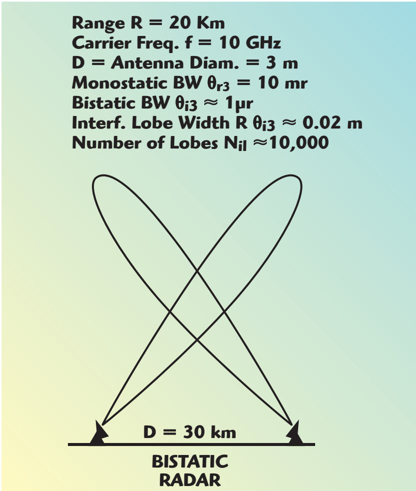
Let us go back to our example in Figure 3b. Consider the linear array consisting of 10 elements λ/2 apart having a length of 5λ. Assume it is used for transmit and receive. It would be useful to compare the angle accuracy we can get, when used as a conventional array with the accuracy obtained when it is used as a MIMO array. A simple back-of-envelope analysis tells us that the MIMO array will have a better angle accuracy, but it is only approximately $\sqrt{2}$ better or, equivalently, the rms angle error is approximately 29 percent smaller.[16] This advantage occurs because, for the MIMO array, we get angle error estimates from the transmit as well as the receive array, whereas, for the conventional array, we get the angle estimate only from the receive array (see Appendix online at www.mwjournal.com/MIMOappendix). The extra signal processing load to do MIMO processing to get the better angular accuracy versus that for the conventional array is large and will not always be warranted at present.

SEARCH VS. TRACK

As pointed out previously, MIMO is efficient for search, not for track. This is because with the MIMO radar, one is illuminating the whole volume that a single MIMO element illuminates. With all the elements assumed identical, they all illuminate the same volume of space. If there is only one target in the volume, most of that energy is wasted. What is wanted for track is a beam focused on the target, with this focused beam formed from the whole array.

It is important to emphasize that the improvement in angle accuracy of the factor of $\sqrt{2}$ is realized for a monostatic full MIMO array system, while doing search of a volume of space. For a linear MIMO monostatic array of N elements, on receive, N focused beams are simultaneously formed that cover the volume of space illuminated by one element. One can think of it as doing track-while-scan. This is one application for which MIMO is well suited. There are situations where this type of search is desired for a conventional system. One such case is where one wants to search out a volume of space, using many receive beams simultaneously, with the volume of space illuminated by one spoiled transmit beam.

The Multi-function Phased Array Radar (MPAR) system, being developed by Lincoln Laboratory as the prime and M/A-COM as the subcontractor with the funding coming from the FAA, has one such mode.[17] MPAR is an effort to develop the next generation air traffic control and national weather surveillance services. Having



▲ *Fig. 7 Bistatic MIMO and bistatic conventional interferometric lobes.*

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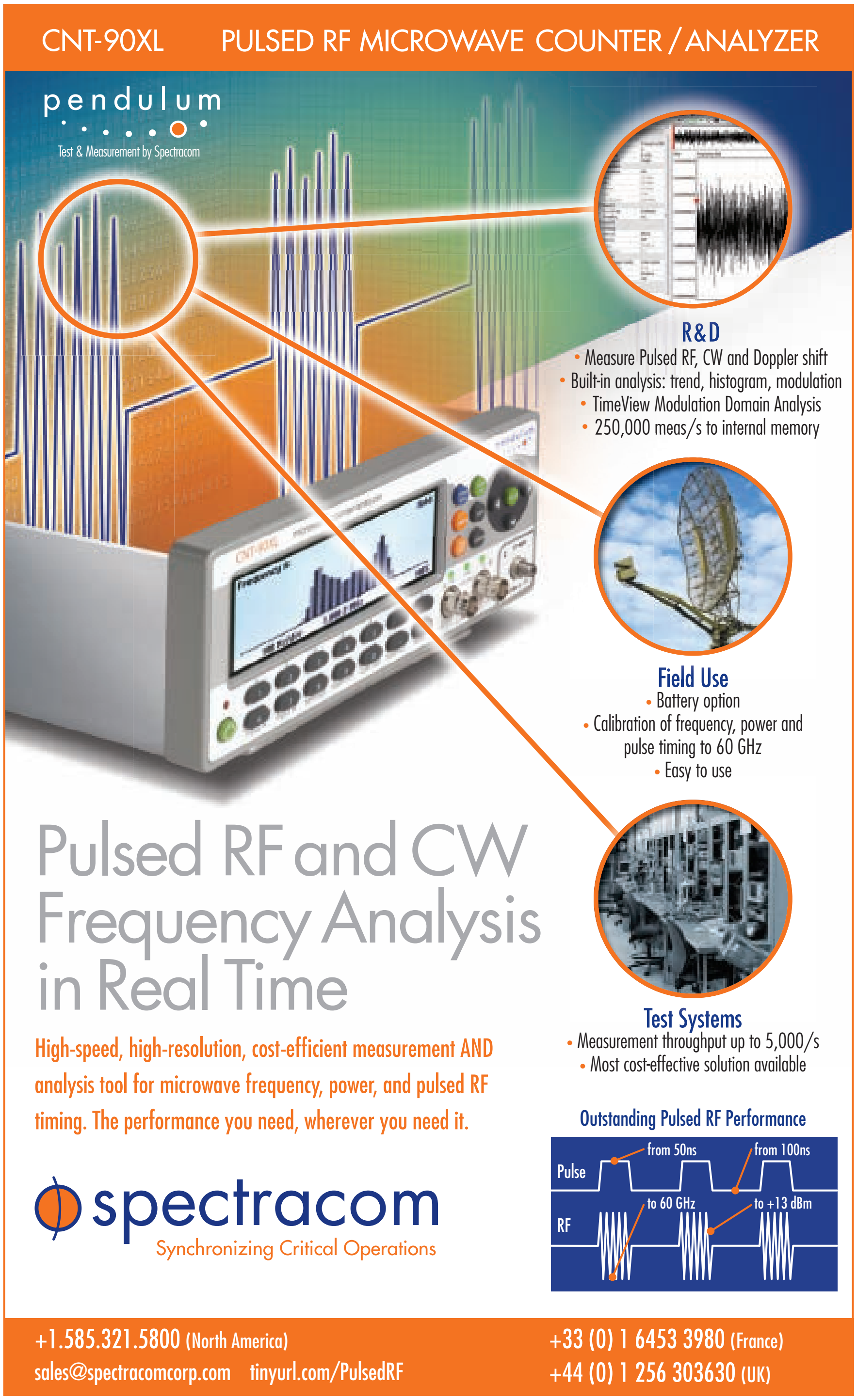
the search mode for the MPAR is desirable in order to search out the volume of space in a short time to keep the occupancy for this search down. Otherwise, one runs out of time. For the MPAR system on receive, 24 beams are generated, consisting of two rows of 12 beams, one above the other to simultaneous search out quickly the volume of space covered by these 24 beams. A spoiled transmit beam is used to illuminate this volume of space on transmit. The 24 receive beams are formed by combining the outputs of the array subarrays. The spoiled transmit beam is formed using the whole array with the spoiling being achieved with possibly a quadratic phase applied across the array. The MPAR uses overlapped subarrays on receive, to avoid generating severe grating lobes in the process of generating these multiple beams from the subarrays.

For a MIMO array system doing the MPAR type search, the receive MIMO array subarray size would be adjusted such that the subarray element size produces a beam that just covers the volume of space to be searched. The overlapped subarrays for the MPAR have approximately a sin x/x illumination, which in turn generates approximately a rectangular subarray beam pattern, which in turn eliminates the generation of severe grating lobes as mentioned previously. For a MIMO system to do the MPAR type of search, using the array subarrays as the elements, it would also be desirable to use overlapped subarrays on transmit, so as to just illuminate the volume to be searched. This is a little more difficult to achieve on transmit for MIMO array. Instead one would use non-overlapped subarrays on transmit that cover the volume of space to be searched.

In the future, when digital beamforming at the element level is cost effective, the volume of space that the subarray MIMO array elements illuminate could be made adaptable. The subarrays would be made to illuminate the volume of the 24 beams to be searched out, or any other number of beams. On receive, 24 or any other number of beams, could be formed just like in the conventional MPAR system. Using MIMO, we would realize the $\sqrt{2}$ improvement in angle accuracy in search over the conventional MPAR system. Also, on receive, these subarrays would be overlapped to avoid grating lobes being formed for the 24 or so receive beams. Right now, the hardware and processing cost required do not appear to warrant the use of MIMO to get this $\sqrt{2}$ improvement.

An alternate conventional system approach for illuminating the volume of space to be searched, other than using a spoiled transmit beam, as done for the above MPAR type system, is to use what is called "machine gunning." With machine gunning, a focused beam is formed on transmit that sequentially illuminates each of the 24 receive beam positions, using pulses that immediately follow one another. This is done before the echoes from any of the pulses are received. After the transmission of the 24 pulses, there is a receive listening period for the echoes. With this approach it is possible to use a different carrier frequency for the beams to avoid interference of the signals between beams.



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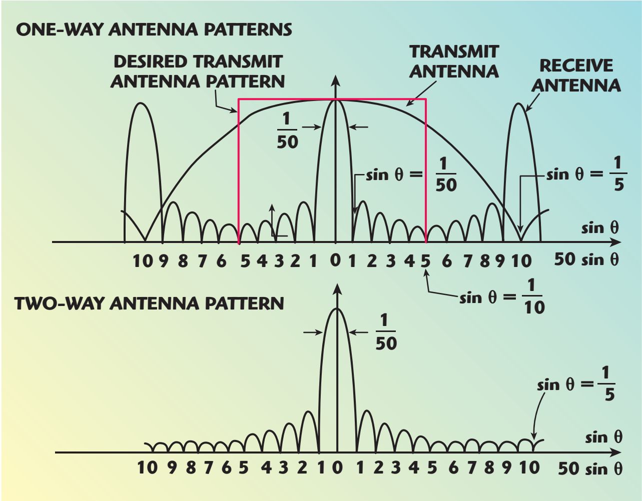

▲ *Fig. 8 Conventional monostatic thinned array antenna patterns: Ideal transmit pattern.*

The advantage of this approach, over beam spoiling, is that the coherence time needed for each of the pulses is 1/H, which is required with beam spoiling, where in the MPAR example, H = 24. Apparently the longer coherence time required by the MPAR system with the use of beam spoiling is not a problem. The H times longer coherence time is needed with the use of beam spoiling, because with the beam spoiling the gain of the antenna on transmit is 1/H times lower than without the spoiling as done with machine gunning.

As indicated in the introduction, the use of the array subarrays for an MPAR MIMO type system, that is SA-MIMO, is better for the efficient use of search energy over using the elements of the array, that is E-MIMO. As pointed out earlier, the 120° horizon fence search example requires more energy to do the search with E-MIMO than with SA-MIMO.

At this point, it is worth going back to the thinned array example of Figure 3a. We showed that the conventional radar, having the thinned receive array and full transmit array, can have approximately the same resolution and accuracy as that of the equivalent MIMO array. This comparison was somewhat unfair, because the MIMO array would be achieving the desired performance for all angles in an element's coverage which, as indicated previously, would be typically approximately 120° for an embedded element gain given by $\cos^n\theta$ with n = 1 to 1.5. For the conventional system, we are illuminating the more limited angle of $\Delta\mu = \pm 1/10$ in u space where $\mu = \sin\theta$ (see Figure 4). This is an angle of +5.7°. Hence, to cover the whole volume with the conventional thinned array, we need to have dwell illuminations that cover the other angles which are needed to cover the 120° scan volume. This is achieved by scanning the transmitter to illuminate these other scan angles during these other dwell times. This is desirable, since we can then adjust the energy needed for the search, dependant on the off-boresite angle, as done for the subarray-MIMO discussed previously. In Figure 4, we show only one focused receive beam covering the azimuth angle $\Delta\mu = 1/50$ at boresite. To cover the angle illumination by the transmit beam of $\Delta\mu = \pm 1/10$, we need to generate simultaneously ten more focused receive beams. These non-boresight beams, however, will have grating lobes, the boresite receive antenna pattern grating lobes at $\mu = \pm 1/5$ in Figure 4 no longer being at the nulls of the transmit pattern. We can eliminate these grating lobes by using a two to three times larger transmit array that has approximately a sin x/x illumination across the transmit antenna, so as to produce an approximately rectangular transmit antenna beam pattern (see ***Figure 8***). Such a rectangular beam pattern would eliminate or nearly eliminate the grating lobes when the transmit beam is pointed at boresite and for all other transmitter scan angles. This solution requires different power levels for the transmit elements for this example but that is not a problem and the power amplifiers can all be operated at saturation (Class C for maximum efficiency). The conventional thinned array will be approximately 3.7 dB more efficient in searching out a 120° horizon fence, than the E-MIMO thinned array; for an ideality factor of n = 1, about 5.2 dB for n = 1.5. We will call the conventional thinned array given by Figure 3a with the transmit antenna extended two to three times the modified-conventional-thinned-array.

Another possible way to achieve a rectangular element pattern for the conventional and MIMO arrays is to use elements that have a nearly rectangular antenna pattern. This could possibly be done with the rod element,[18,19] if one only needed to cover the angle covered by the 3 dB transmit beamwidth of Figure 4. The rod element has approximately a rectangular antenna pattern.

Because our conventional thinned array system of Figure 3a has the same resolution as its MIMO equivalent system, it will be able to resolve as many targets occurring simultaneously in the coverage region, as does its MIMO equivalent and the MIMO equivalent full array of Figure 3c. Because it has the same resolution, it will also be able to estimate the parameters of these targets just as well as its MIMO equivalent system does. This is contrary to the results given[1, Sect. 1.3] for thinned MIMO array systems. The reason for this difference is that for the conventional array, a single element is assumed for the transmit antenna and a full array of N elements for the receive antenna. This is the wrong combination to use for the comparison. In our comparison to achieve equivalence, we use a full transmit array of M elements, equal to about 20, to achieve the nearly rectangular transmit beam pattern shown in Figure 8. For receive we use a thinned array identical to the MIMO thinned array.

If the thinned array example given only had to cover a horizon fence $2\sin^{-1} 0.1 = 11.5°$ wide at boresite, the modified-conventional-thinned-array would be approximately 10 dB more efficient than the E-MIMO thinned array when n = 1, approximately 9 dB for n = 1.5.

ISSUE OF COHERENCE TIME NEEDED WITH MIMO VS. CONVENTIONAL ARRAY

Often, it is indicated that an N element MIMO array has the disadvantage of requiring N times the coherence integration time as needed when using a conventional array. Here again an apples to oranges comparison is being made. This comparison is only true when comparing a MIMO system of N antenna elements with a conventional array system using the

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TABLE I
MIMO MONOSTATIC ARRAY OF N ELEMENTS NUMBER OF MATCHED FILTERS AND WEIGHTS

Item	Amount	Number for N =		
		10	100	1000
MF	$\geq N^2$	≥ 100	$\geq 10{,}000$	$\geq 10^6$
W_{Tijk}	$\geq N^2$ Per Beam	≥ 100	$\geq 10{,}000$	$\geq 10^6$
W_{Tijk}	$\geq N^3$ For N Beams	≥ 1000	$\geq 10^6$	$\geq 10^9$
W_{Rik}	$\geq N^2$ For N Beams	≥ 100	$\geq 10{,}000$	$\geq 10^6$

same array of N array elements, but with either: (1) the conventional array is searching out the whole volume of space sequentially with one transmit and receive focused beam; or else, (2) the conventional array is searching the volume of space with multiple focused beams, N, being formed simultaneously on receive and machine gunning being used on transmit. If instead for the conventional system beam spoiling is used, transmit as done with the Lincoln Laboratory MPAR, the coherent integration time for the conventional MPAR type system is the same as the equivalent MIMO system. Searching the volume of space with a conventional system using one transmit and receive beam is not efficient. It requires N times the search time that is needed with machine gunning on transmit or with beam spoiling on transmit and using in both cases N simultaneous receive beams.

PROCESSING COMPLEXITY ACCRUED WITH MIMO

Assume a monostatic full (that is non-thinned) array of N elements. With MIMO, the whole volume would be searched out by forming N focused transmit beams that cover the volume of space to be searched.[22] These beams would be formed in the receiver. Each of the N receiver elements will have N matched filters (MF), (see Figure 2 and ***Table 1***). These N matched filters are needed to process the N orthogonal or diverse waveforms transmitted from the N transmitter elements. Since there are N such receiver elements with each having N MFs, N^2 matched filters are needed for the pulse compression in the MIMO system of one focused transmit beam. The N^2 MFs used to form the kth beam are also shared to form the other k = 1 to N transmit beams. Thus to form the N transmit beams N^2 MFs are needed. Following the N^2 MFs for the kth beam formation are the weights W_{Tijk} that contain the phase shifts needed to focus the kth transmit beam in the direction of the kth beam. For the N^2 MFs outputs for the kth beam, N^2 weights are needed, because i = 1 to N and j = 1 to N for a given kth beam, the receiver elements being indexed as "i" and the transmit waveform from the "jth" transmit element being indexed as "j". To form the kth transmit beam the receiver weight outputs are com-

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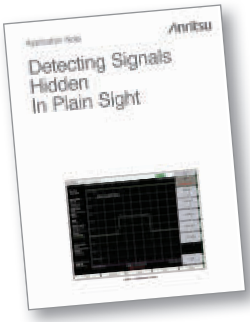

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TABLE II
MIMO MONOSTATIC ARRAY OF N ELEMENTS NUMBER OF BEAMS

Item	Amount	Number for N =		
		10	100	1000
Beams	$\geq N^2+N$	≥ 110	$\geq 10{,}100$	$\geq 10^6$

bined for the ith element to form the output E_{ik}. This is done for the other elements to form E_{ik}, i = 1 to N (see Figure 2). These outputs are in turn combined with the weights W_{Rik}, i = 1 to N, to form the kth receive focused beam output E_k (see Figure 2). A total of $N^2 + N$ weights W_{Tijk} and W_{Rik} are thus used to form the kth focused receive beam or approximately N^2 for N » 1. Finally for the N receive beams, a total of $N^3 + N^2$ such weights are thus needed or ~N^3 for N » 1. The transmit and receive beams are identical (overlapping in space) here for this monostatic MIMO system, where the same array is used for both transmit and receive. Hence the indexing k is identical for the receive and transmit beams. Because k = 1 to N there are a total of N^2 transmit beams that are formed. Finally N receive beams are formed. Thus for the MIMO system $N^2 + N$ beams are formed to generate the N receive beams (see ***Table 2***). The above discussion did not take into account Doppler variance. Recall that with Doppler variance a bank of F Doppler MF for each orthogonal or diverse waveform is required and as a result F times more MFs and weights would be needed.

Let us compare the SA-MIMO with a conventional radar regarding the computation needed. For both we shall assume N subarrays of the same size. We shall assume that the space to be searched is equal to the volume illuminated by one subarray, however, for the conventional array we shall form the transmit beam by using the whole array with beam spoiling. On receive for both we are covering the whole volume of space using N simultaneous receive focused beams as done by the SA-MIMO array. This would give a fair comparison. For the conventional radar, only N MFs are needed, versus FN^2 for the SA-MIMO radar, a factor of FN more for the SA-MIMO radar. For the conventional radar only N^2+N weights are needed, N on transmit to form the one spoiled beam and N^2 on receive to form the N focused receive beams. For the SA-MIMO, we need FN^3+FN^2 weights, a factor of FN more. For N = 100 we are talking about F times 10,000 MFs for the SA-MIMO radar versus 100 for the conventional radar, using a chirp waveform. There are cases where linear FM waveforms can be used for the MIMO system, like for OTH systems.[2,20] The ≥ in Figures 9 and 10 is to allow for the possibility of Doppler intolerance for the MIMO radar.

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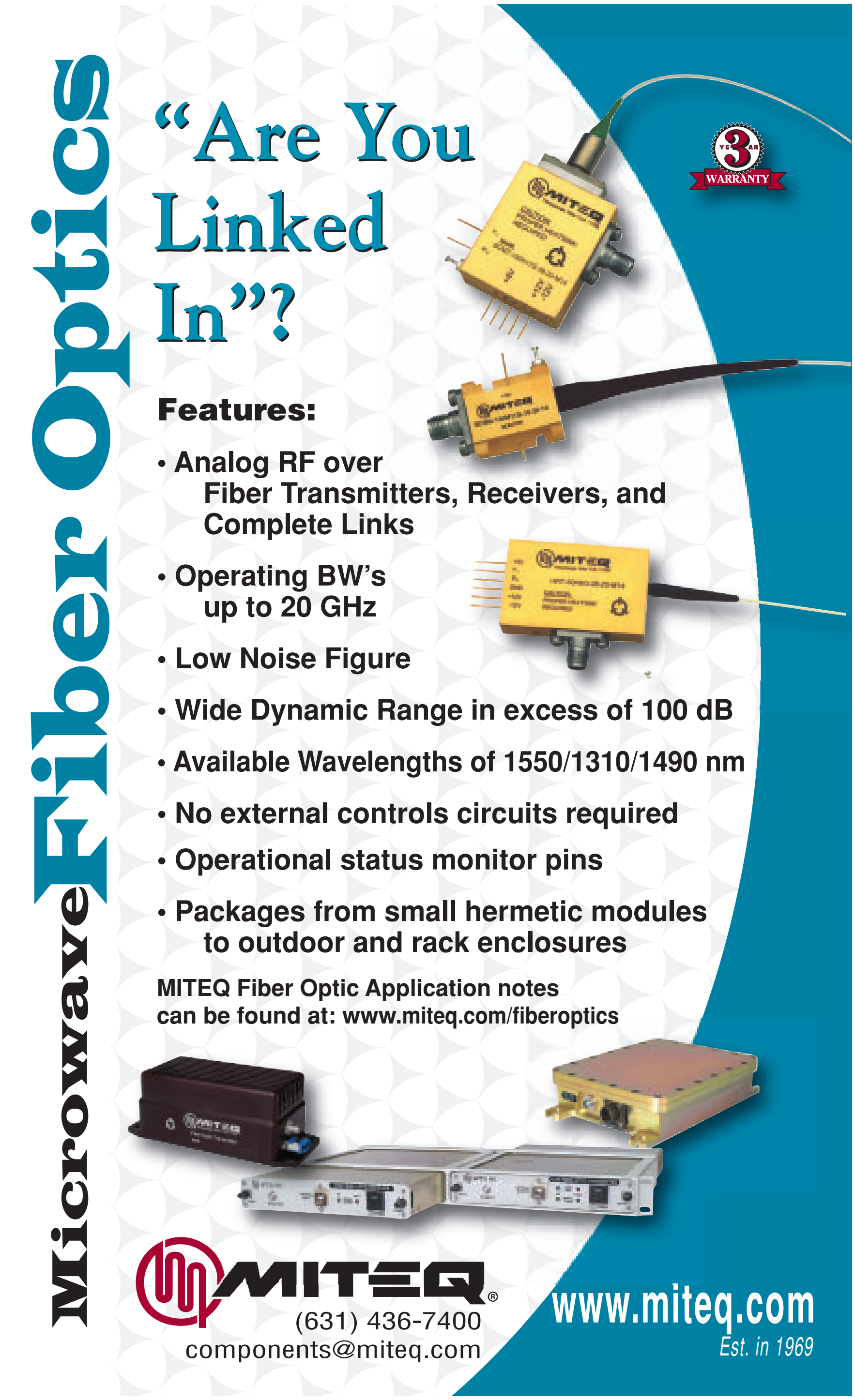
transmit beam as well as in the receive beams where there is clutter. Assume again a MIMO linear full array of N elements used for both transmit and receive. It was indicated previously that $N^2 + N$ weights are needed to form the one beam. Thus an $N^2 + N$ by $N^2 + N$ matrix has to be inverted to form one beam adaptively. For N = 1000 we need to invert approximately a million by a million array. For N = 100 we need to invert a 10,000 by 10,000 element array. In either case, this is a lot of computations and we have not taken into account Doppler intolerance. For a conventional array, we can easily achieve the same result. Specifically, we can put nulls in the transmit beam in the direction of clutter if we have a clutter map or if we know in advance where the clutter is. For example in a ground based or ship based radar we know the clutter is at the horizon so we put a null in the antenna transmit pattern as well as in the receive pattern for the sidelobes on the horizon. Thus we do not always need MIMO to put nulls in the transmit pattern. The extra degrees of freedom (DOF) the MIMO brings come at a high computation cost. Right now, we are having a problem in our systems handling the DOF we have with our conventional arrays. We cannot do the adaptive nulling at the element level or even at the subarray level in many applications. It is too costly in computations. Li and Himed consider the use of transmit subarrays for MIMO, TS-MIMO, to reduce the computation load for putting nulls in the direction of interference.[24]



WHERE MIMO IS USEFUL AT PRESENT AND THE NEAR TERM

Two radars in close proximity are useful for cohering on transmit and receive (see ***Figure 9***).[4-6,21] It provides a 9 dB improvement in PAG or equivalently SNR for a target being detected or tracked. For search, it provides a 6 dB advantage in PA. This is not without a cost. It requires that during the time of the combining, both radars be used for tracking one target or for searching the same volume of space. This is the one application that can provide an order of magnitude improvement in angle accuracy. MIT Lincoln Laboratory has demonstrated the combining in real time of dish radars using MIMO.[21,22]

Brookner et al. describes a patented incoherent MIMO technique for combining two radars.[7] It uses different carrier frequencies for the two radars. This technique has the advantage of providing an 8.7 dB improvement in sensitivity for a Swerling 2 target for a 90 percent detection. This improvement is realized by choosing the carrier frequencies far enough apart to provide independence of the echo amplitude returns for the two frequencies. For a Swirling 1 target, the frequency diversity then lowers the target fluctuation loss to the point of almost making up for the video integration loss.

It would be useful for monostatic radar applications where the size of the antenna must be small and a 29 percent reduction in antenna size would be important. No doubt MIMO will find practical uses in the future as signal processing continues to get less expensive. Another near term potential candidate for MIMO is the OTH radar. MIT Lincoln Laboratory and the

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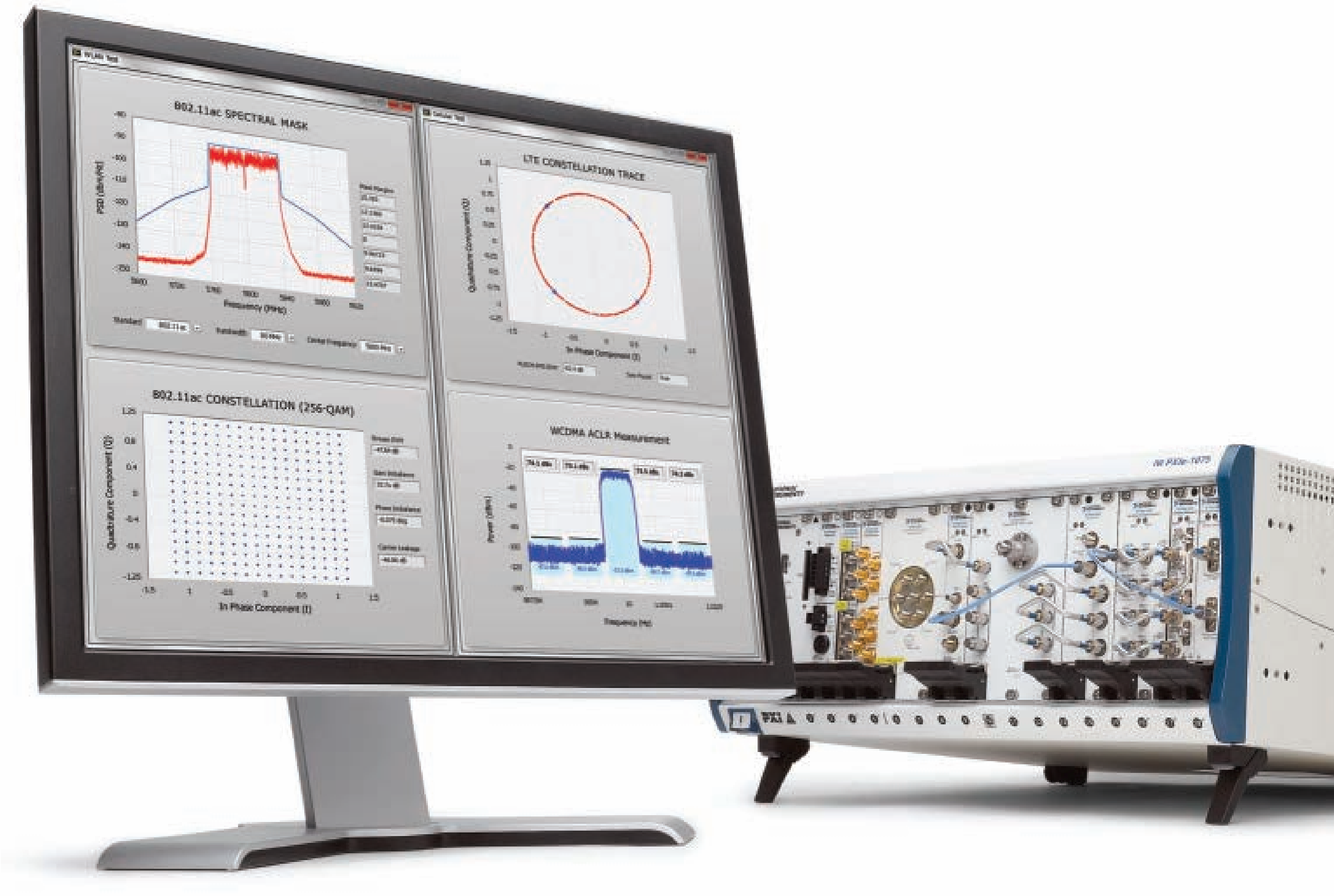

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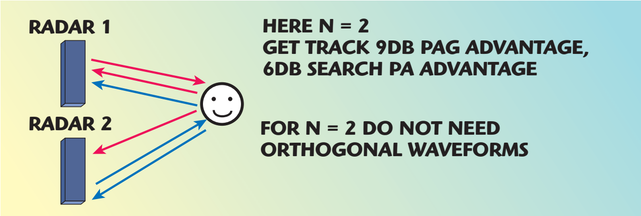
Australians have been doing work in this area.[20,22,23] OTH looks like a good application, because there are not too many elements and the bandwidth is small so the processing is not excessive. Figure 1 shows the architecture for a bistatic MIMO system which applies for an OTH system where the transmit and receive antennas are usually separated.■



▲ *Fig. 9 Coherently combine N radars: (Bob Enzmann/George Thome & Leon Green patents[4-6]; see also Coutts & Coumo, IEEE SAM 2006, Boston[21] and Brookner patent[7]).*

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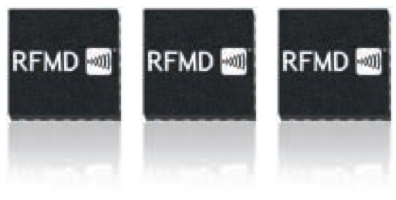

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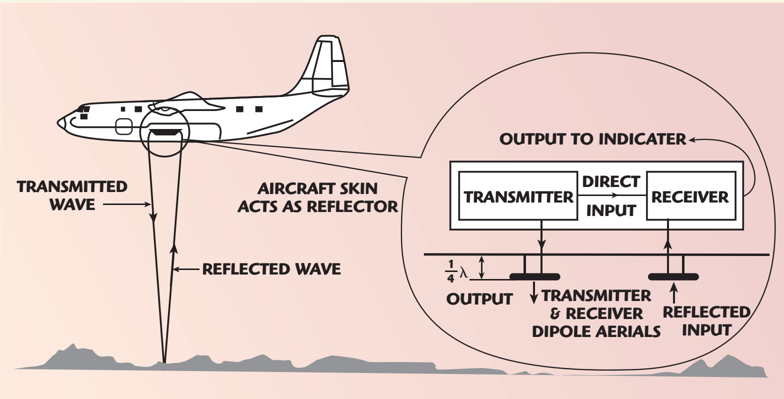
Next Generation Radar Altimeter Testing

Radar altimeters (or radio altimeters) have been used on aircraft since the mid-1950s. Together with barometric pressure altimeters and more recently GPS and radio timing positioning systems, radar altimeters are a critical part of modern aircraft avionics that increase flight safety, reliability and capability.

Radar altimeters are primarily used during flight at altitudes below 5000 feet and are key tools for critical maneuvers, including take-off and landing approaches. Low flying aircraft, like helicopters and Unmanned Aerial Vehicles (UAV), rely on radar altimeters (RA) for nearly all operations. UAV and some manned aircraft may be operated remotely, consequently the success of the mission and safety of the passengers and crew are dependent on the accuracy and performance of the RA. Verifying performance and calibrating RAs quickly and reliably take place at RA manufacturing sites, calibration centers and flight line avionics depots. The capability of the necessary test equipment varies based on the site. For example, during RA product development and qualification, detailed testing over a variety of environmental and performance conditions are necessary, whereas flight line testing may only include verification test at a few altitudes. Calibration requires NIST-traceable standards testing to ensure accuracy. Depending upon the test site and requirements, a variety of test tools may be selected, based on cost, capability, ease of use and reliability. Eastern OptX has produced equipment for use in each of these applications and has optimized the performance to meet the testing needs with rugged and competitive systems.

Historically, RAs have used a Frequency Modulated Continuous Wave (FMCW) scheme because it is capable of achieving the low altitude accuracy required with a simple and reliable system. ***Figure 1*** shows the FMCW system. An RF signal (typically 4.3 GHz) is modulated with a swept IF signal, typically from 400 to 440 MHz. The rate of change of the sweep is typically 0.2 MHz per second. That signal is then transmitted from an antenna mounted on the underside of the aircraft, typically in the forward section and radiated toward the earth. The signal reflected from the earth is then detected using a separate receive antenna located some distance from the transmit antenna. Care must be taken to provide isolation between the two antennae to avoid stray paths that might be confused with the aircraft-to-earth path, particularly at low



▲ *Fig. 1 The altitude is given by A = c |Δf|/(2(df/dt)) (Dick Barrett, Radar Theory, 2000-2002).*

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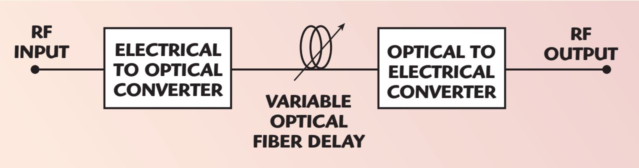

▲ *Fig. 2 Typical fiber optic delay line.*

altitudes. The received signal is mixed with a sample of the broadcast signal and the resulting frequency difference (Δf) is directly proportional to the round trip distance between the aircraft and the earth. The FM span and slew rate are selected to optimize distance measurement accuracy at near-earth altitudes.

There are several methods used to test RAs. One of the most compact, accurate and reliable is the Fiber Optic Delay Line (FODL) method. The FODL method exploits the small size, lightweight, low loss and low drift properties of optical fiber transmission lines to create a system that replicates the channel properties that RAs face in actual operation. ***Figure 2*** shows a typical FODL used for RA testing.

The RF signal transmitted from the altimeter is used to modulate a broadband optical laser and the output of the laser passes through a variable delay line. The delay line distance may be adjusted to match a desired altitude and the delay output is converted back into an electrical signal using an optical detector. The RF output is then used as the input to the altimeter receiver. The optical delay provides a precise altitude with accuracy better than 0.1 percent and offers steady, repeatable performance.

▲ *Fig. 3 The EA-6061 altimeter test set.*

EA-6061 ALTIMETER TEST SET

Eastern OptX has introduced the EA-6061 altimeter test set that is targeted at RA calibration and system design. The EA-6061 is an automated system with variable delay and calibrated propagation loss. Operating with any altimeter transmission protocol, it is easy to use from either the front panel touch screen or via remote commands. The GUI provides access to built-in self-test and both manual and coupled operation with user-selectable aircraft cable compensation. ***Figure 3*** shows the EA-6061 altimeter test set.

EA-6061 system details:

- Altitude: Variable, 0 to 6350 ft in 50 ft steps
- Propagation loss: Locked to altitude setting or user controlled
- Aircraft cable compensation: Four user-defined settings
- Calibration: Built-in self calibration with short and open I/O options
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USB-2SPDT-A18	2	0.25	1.2	80	10	685.00
USB-3SPDT-A18	3	0.25	1.2	80	10	980.00
USB-4SPDT-A18	4	0.25	1.2	80	10	1180.00
NEW USB-8SPDT-A18	8	0.25	1.2	80	10	2495.00

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IF/RF MICROWAVE COMPONENTS

Fig. 4 The EA-6071 altimeter test set.

EA-6071 ALTIMETER TEST SET

For depot level or production testing, Eastern OptX introduces the EA-6071. This system provides an economical easy-to-operate system that is small, lightweight and offers a battery power option for operation on the flight line. The convenient user interface makes operator training quick and reduces the chance of set-up errors during RA testing. This is a great tool for quick RA performance verification and, with better than 1 percent accuracy, may be used to calibrate the RAs well. Annual system verification is recommended, however calibration is not required. **Figure 4** shows the EA-6071 altimeter test set.

EA-6071 system details:

- Altitude: Fixed, 0, 250, 500 and 1000 ft
- Propagation loss: Locked to altitude setting
- Aircraft cable compensation: Three user-defined settings
- Front panel rotary switch control
- External delay option

In addition to operation with CWFM systems, FODL devices will operate with any in-band signal regardless of the modulation type, encryption, frequency agile, or spread spectrum modes. This advantage also allows the system to be used for altimeter development, since it accepts any and all signal variations as long as they are in-band. The typical bandwidth of fiber optic systems varies between 0.1 to 18 GHz. This feature is especially useful with modern Low Probability of Intercept (LPI) radar altimeters. LPI systems are designed to minimize signal detection and subsequent source and target location. Primarily used on military aircraft, LPI RAs reduce source detection using the following methods:

- Frequency-hopping (spread spectrum) RF signal to reduce RF energy at a particular frequency and lower the signal power to near background noise levels
- Pseudo-random hopping algorithms
- Encrypted transmission data
- Transmission power management to minimize signal level to the minimum required for altimeter detection

Both the EA-6061 and EA-6071 provide testing for FMCW and LPI RAs, without any special modification. As the use of LPI RAs increases, particularly on UAVs, there will be additional need for fast calibration and verification of performance using FODL devices. FODLs may also be incorporated into aircraft for onboard RA self-test and alignment. Additional FODL features, including multipath and Doppler shift replication, help designers test existing hardware as well as next generation altimeter designs without the need for costly and untried test systems.

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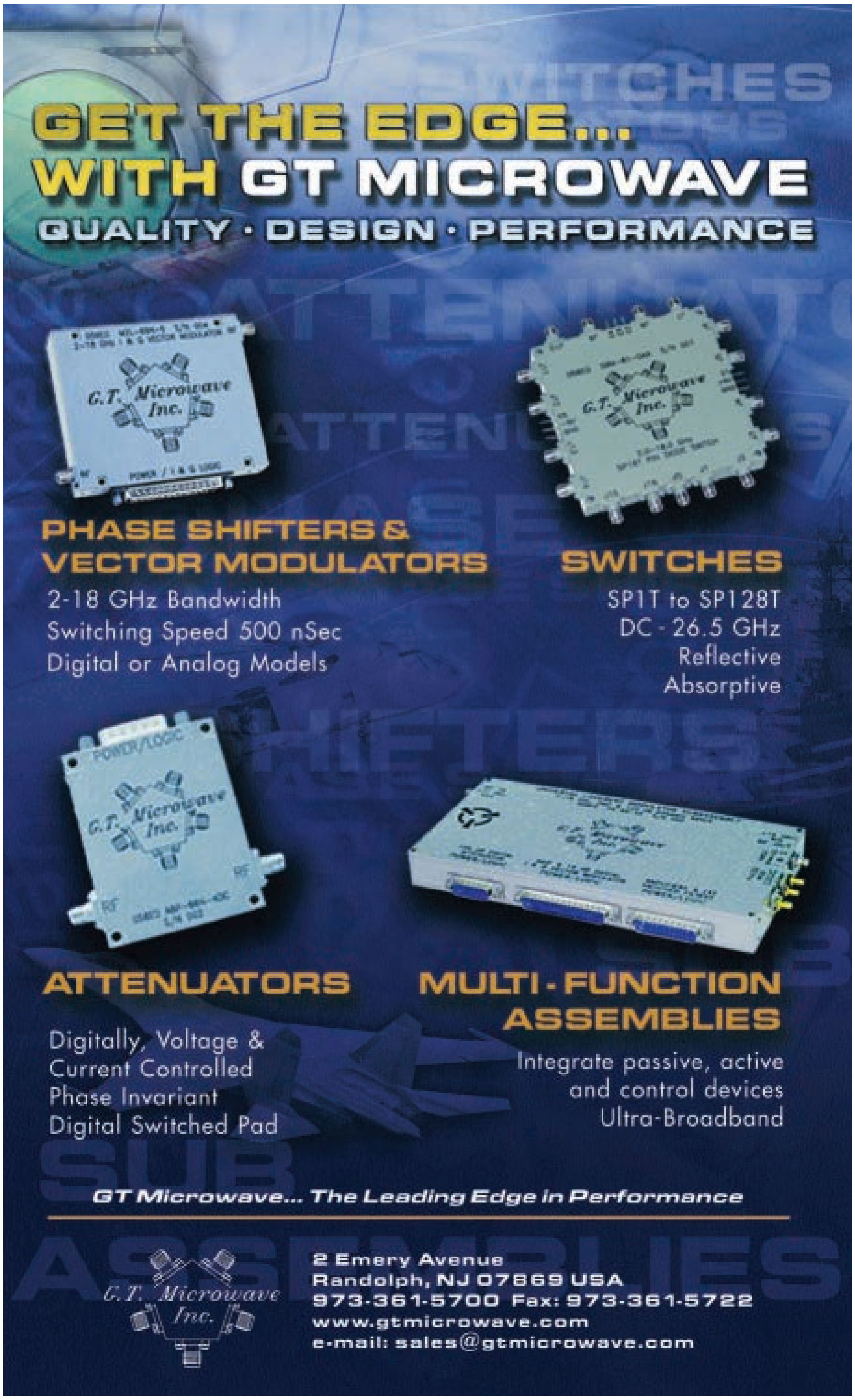

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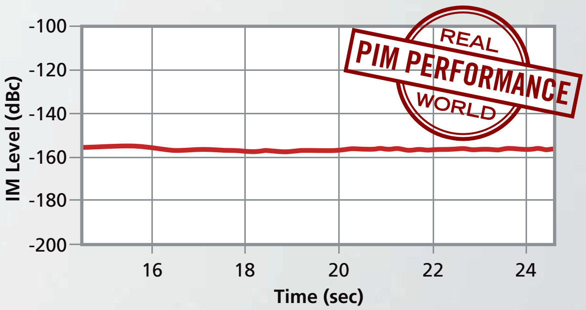

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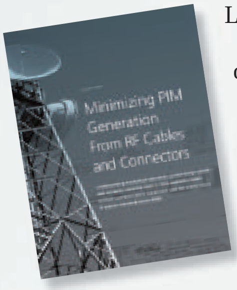

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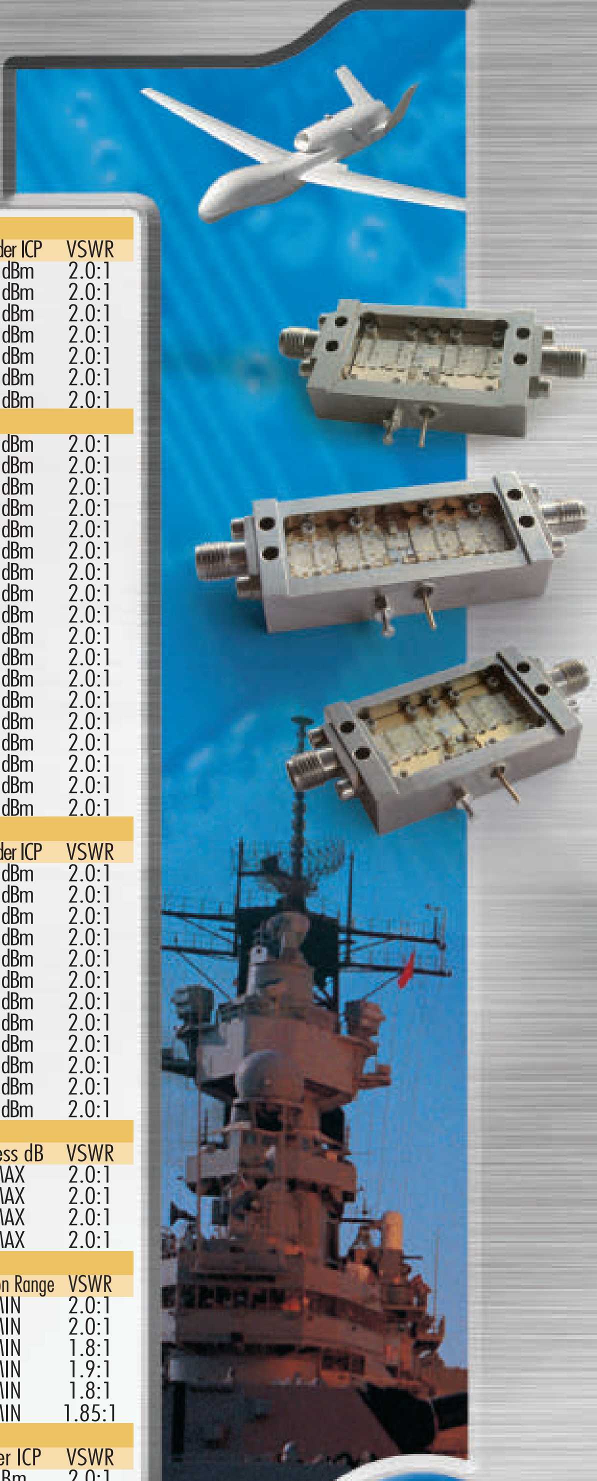

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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Defense News

Dan Massé, Associate Technical Editor

CHAMP – Lights Out

A recent weapons flight test in the Utah desert may change future warfare after the missile successfully defeated electronic targets with little to no collateral damage. Boeing and the U.S. Air Force Research Laboratory (AFRL) Directed Energy Directorate, Kirtland Air Force Base, NM, successfully tested the Counter-electronics High-powered Microwave Advanced Missile Project (CHAMP) during a flight over the Utah Test and Training Range.

CHAMP, which renders electronic targets useless, is a non-kinetic alternative to traditional explosive weapons that use the energy of motion to defeat a target. During the test, the CHAMP missile navigated a pre-programmed flight plan and emitted bursts of high-powered energy, effectively knocking out the target's data and electronic subsystems. CHAMP allows for selective high-frequency radio wave strikes against numerous targets during a single mission.

"This technology marks a new era in modern-day warfare," said Keith Coleman, CHAMP program manager for Boeing Phantom Works. "In the near future, this technology may be used to render an enemy's electronic and data systems useless even before the first troops or aircraft arrive."

MEADS Successfully Intercepts Air-Breathing Target

The Medium Extended Air Defense System (MEADS) detected, tracked, intercepted and destroyed an air-breathing target in its first-ever intercept flight test at White Sands Missile Range, NM. The test achieved all criteria for success.

"...demonstrates MEADS' ability to identify, track, engage and defeat targets attacking from any direction"

MEADS is a next-generation, ground-mobile air and missile defense system that incorporates 360° radars, netted and distributed battle management, easily transportable launchers and the hit-to-kill PAC-3 Missile Segment Enhancement (MSE) Missile. The ...system combines superior battlefield protection with new flexibility to protect forces and critical assets against tactical ballistic missiles, cruise missiles, unmanned aerial vehicles and aircraft.

The MEADS test configuration included a networked MEADS battle manager, lightweight launcher firing a PAC-3 MSE Certified Missile Round and a 360° MEADS Multifunction Fire Control Radar (MFCR), which tracked the MQM-107 target and guided the missile to a successful intercept.

"This successful flight test further demonstrates MEADS' ability to identify, track, engage and defeat targets attacking from any direction using a single mobile launcher," said NATO MEADS Management Agency general manager Gregory Kee. "MEADS is proving its capability to defend our warfighters and key assets against a growing 21st century threat."

The test exploited the MEADS capability for full-perimeter, 360° defense, with the PAC-3 MSE Missile performing a unique over-the-shoulder maneuver to defeat the target attacking from behind the MEADS emplacement.

"MEADS provides advanced capabilities that detect, track and intercept evolving threats from farther away and without blind spots," said MEADS International president Dave Berganini. "This successful intercept proves MEADS' advertised capabilities are real. Its digital designs and modern hardware and software ensure high reliability rates and dramatically reduced operational and support costs."

The MFCR is an X-Band, solid-state, active electronically scanned array radar that provides precision tracking and wideband discrimination and classification capabilities. For extremely rapid deployments, the MEADS MFCR can provide both surveillance and fire control capabilities until a surveillance radar joins the network. An advanced identify friend-or-foe subsystem supports improved passive threat identification and typing. Using its 360° defensive capability, the advanced MEADS radars and the PAC-3 MSE Missile, MEADS defends up to eight times the coverage area with far fewer system assets and significantly reduces demand for deployed personnel and equipment, which reduces demand for airlift. MEADS successfully completed its first flight test on November 17, 2011, against a simulated target attacking from behind. A PAC-3 MSE Certified Missile Round was employed during the test along with the MEADS lightweight launcher and battle manager.

Patriot Air and Missile Defense Systems Get Smarter, Faster and Tougher

Deep inside the factory where Patriot defense systems are made, Ken Arruda stopped beside a rolling cart and pointed to a white card sprinkled with what looked like grains of sand. They were computer chips for the Patriot's radar system – parts that since 2006 have shrunk to one-eighth their previous size.

"Now they're as small as a speck of pepper," said Arruda, operations director for Raytheon's air defense programs. "That's how far Patriot has come in the last few years."

And tiny chips are just the start. From the tip of its nose cone to the base of its radar, designers have invested more than $400 million in the last four years as part of a program aimed at making the legendary air and missile defense system faster, smarter and tougher. Miniature components have replaced racks of equipment. Touchscreens have replaced control panels. New machines in Raytheon's

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Andover, MA factory are making parts lighter, stronger and longer-lasting.

The U.S. government and other partners in the program have helped fund the modernization, but it was an order for new Patriot systems for the United Arab Emirates that gave designers the chance to reengineer Patriot from the ground up in late 2008. The system had already gone through several upgrades since its debut in the first Gulf War. But designers gave the Patriot missile a faster, more accurate guidance system known as Guidance-Enhanced Missile – Tactical, or GEM-T. They rewired circuits in the radar and command stations, shrinking and speeding up components. The missile's mobile control room got a major makeover, with huge touch screens, faster computers and sleek black keyboards replacing banks of controls.

"How we have prepared it for success in the future is really remarkable," said Glenn Walker, a business development manager for Raytheon's Integrated Air and Missile Defense.

Denmark Selects U.S. Navy's MH-60R SEAHAWK Helicopter

The U.S. Navy announced that the Danish government signed an official letter of offer and acceptance formalizing its intent to buy nine MH-60R SEAHAWK® helicopters and comprehensive logistics support for its Maritime Helicopter Replacement Program.

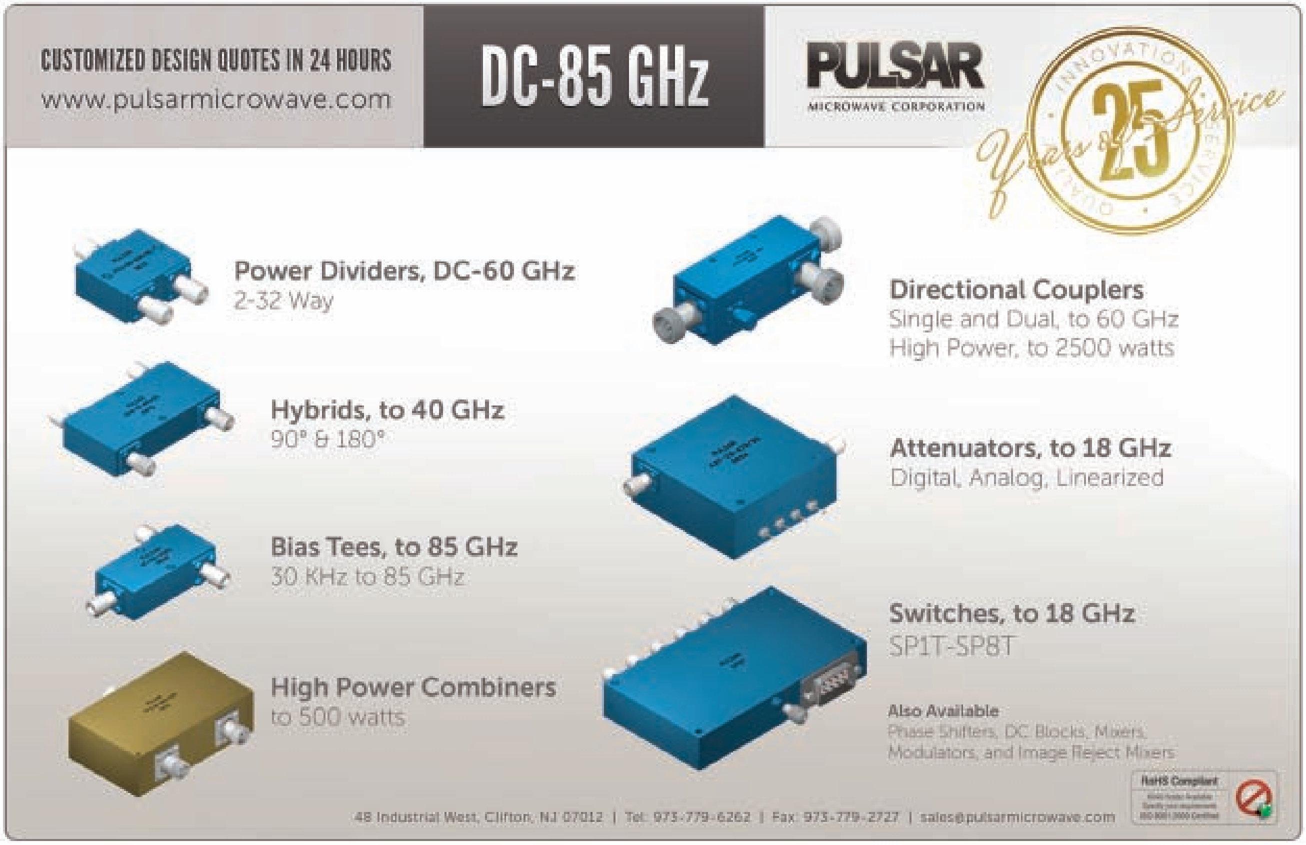
Valued at U.S. $686 million (Kr 4 billion), the aircraft will be procured via the U.S. government's Foreign Military Sales program.

"It's great news that the Danish government has selected the U.S. Navy's MH-60R, an aircraft we believe is the world's most capable multi-mission maritime helicopter," said Rear Adm. Paul Grosklags, Program Executive Officer, Air, ASW, Assault and Special Mission Programs. "Danish pilots and crew will be able to fly with the confidence that these aircraft have been proven operationally capable at sea and have the full logistics support already in place to ensure they are ready and able to fly anytime, anywhere in the world."

Denmark is the second country to buy MH-60R helicopters following Australia's purchase of 24 aircraft in 2011. All nine aircraft will be delivered to the Danish government by 2018.

The Danish aircraft are configured for anti-surface warfare operations, including defending Danish interests in the North Atlantic, executing anti-piracy operations, and conducting other missions during international deployments.

The U.S. Navy was supported in its winning proposal by Team Seahawk, consisting of MH-60R airframe manufacturer Sikorsky Aircraft, mission systems integrator Lockheed Martin, engine manufacturer GE, sensor supplier Raytheon Corp., and training supplier CAE.



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UK MoD Electronic Surveillance R&D Programme Launched

The Communications and Cross-Cutting Electronic Surveillance (CCCES) research programme will investigate novel technologies and techniques in support of future UK MoD electronic surveillance procurements. The programme will be delivered by the Collaborative Research in Electronic Surveillance Technology (CREST) consortium, in close collaboration with the Defence Science and Technology Laboratory (Dstl). CREST is led jointly by QinetiQ and Roke Manor Research with QinetiQ also providing the overall programme management.

The programme has a primary focus on communications electronic surveillance but with elements encompassing radar transmissions. A key feature of the research will be to undertake field demonstrations to assist in the de-risking of advanced signal processing techniques.

"...future UK electronic surveillance requirements can be met more rapidly with reduced risk and at lower cost..."

Dr. Giles Bond, CREST consortium co-lead and manager of QinetiQ's electronic warfare and radar business, said, "CREST will deliver outputs across a range of technology readiness levels, spanning innovative research and technology demonstrator systems. The focus will be on using advanced signal processing hosted on software-reconfigurable hardware architectures to prove how future UK electronic surveillance requirements can be met more rapidly with reduced risk and at lower cost than is currently possible."

Chris Tarran, the co-lead for Roke, added, "We are delighted to be at the hub of this important research and demonstration programme which will help to underpin the future of UK ES technology. In particular, we are focussing on the future challenges faced with urban operations, and the need for low size, weight and power electronic surveillance solutions with a capability against the complex urban signal and propagation environments."

The CREST consortium will also bring together the wider electronic surveillance community in the UK to gain access to a wide supplier base, which will include small and medium sized enterprises and a selection of universities.

METIS Paves Way for Future Communications Systems

The Mobile and wireless communications Enablers for the Twenty-twenty (2020) Information Society (METIS), research project started in November 2012. It is co-funded by the European Commission as an Integrated Project under the Seventh Framework Programme (FP7), which will receive €16 million of its €27 million budget from the EU.

METIS is a consortium of 29 partners spanning telecommunications manufacturers, network operators, the automotive industry and academia. The project's objective is to respond to societal challenges for the year 2020 and beyond by laying the foundation for next generation mobile and wireless communications systems.

METIS will lay the foundation for the future '5G' mobile and wireless communications system, consisting of the evolution of currently-existing wireless technology and any new wireless technology needed to fully enable the networked society. It will develop a system concept that delivers the necessary efficiency, versatility and scalability. The project will investigate key technology components supporting the system, and will also evaluate and demonstrate key functionalities.

...laying the foundation for next generation mobile and wireless communications systems.

METIS will provide a proof-of-concept by means of simulations and test beds. In particular, it will demonstrate through hardware test beds key technology components developed in the project. METIS intends to enable European lead on the development of the future mobile and wireless communications system, and ensure an early global consensus on these systems. The project will play an important role in building consensus among other external major stakeholders prior to global standardization activities. This will be done by initiating and addressing work in relevant global forums (e.g., ITU-R), as well as in national and regional regulatory bodies.

ETSI and IEEE-SA Renew MoU

The European Telecommunications Standards Institute (ETSI) and the IEEE Standards Association (IEEE-SA) have renewed their memorandum of understanding (MoU). This agreement continues the long-standing cooperation between the two organizations, fosters collaboration between them, and further promotes mutual interests through global standards coordination.

To formally acknowledge the alliance, Luis Jorge Romero, director-general of ETSI, and Konstantinos Karachalios, managing director for IEEE-SA, gathered with members of the Institute for a signing ceremony during the 60th ETSI General Assembly in Mandelieu, France. During the ceremony, the two organizations acknowledged the need for IEEE-SA and ETSI to work closely together on coordinated standards to avoid duplicated work and align under a mutually beneficial framework.

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"Sharing information is the key factor..."

"ETSI is the ideal partner for IEEE-SA's continued progress on expanding cooperation between technical committees with a global reach," said Karachalios. "Sharing information is the key factor here. Collaboration between governing bodies is top of mind. It's all part of our vision for widespread adoption of globally relevant standards and our commitment to work cohesively with standards organizations around the world."

"The framework for coordination between technical groups will greatly benefit industry as it increasingly relies on standards for interoperability," said Romero. "This agreement will allow ETSI representatives to become more knowledgeable about IEEE activities and vice versa, of course."

EDRS Space Network Gets Go-Ahead

The design of Europe's data relay satellite system – EDRS – has been completed and approved, which marks the moment when it moves ahead with a green light from its first customer, the Global Monitoring for Environment and Security (GMES) initiative from the European Union.

EDRS will be the first commercially operated data relay system to deliver services to the Earth observation community. It is being built through a Public-Private Partnership (PPP) between ESA and Astrium Services, using payloads carried by two satellites in geostationary orbit above the Equator.

"EDRS is a fantastic breakthrough for Europe..."

Data transmitted from satellites in lower orbits to either of these EDRS payloads can then be relayed to the ground. The payload includes a laser terminal developed by TESAT of Germany to transmit up to 1.8 Gb per second over distances in excess of 40,000 km, between the lower satellites and EDRS in geostationary orbit.

"EDRS is a fantastic breakthrough for Europe, from the innovative laser communication terminal technology, which is the heart of EDRS, to the provision of operational services by 2014, through a PPP that combines the best from European space companies with the national and European space institutions," said Magali Vaissiere, director of ESA's Telecommunications and Integrated Applications Directorate.

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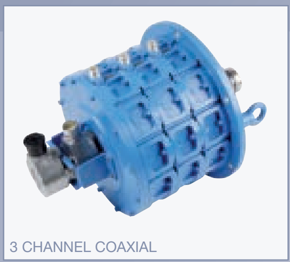

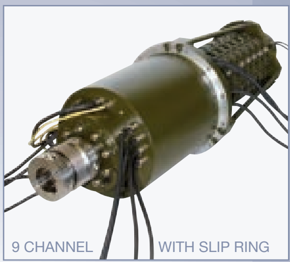

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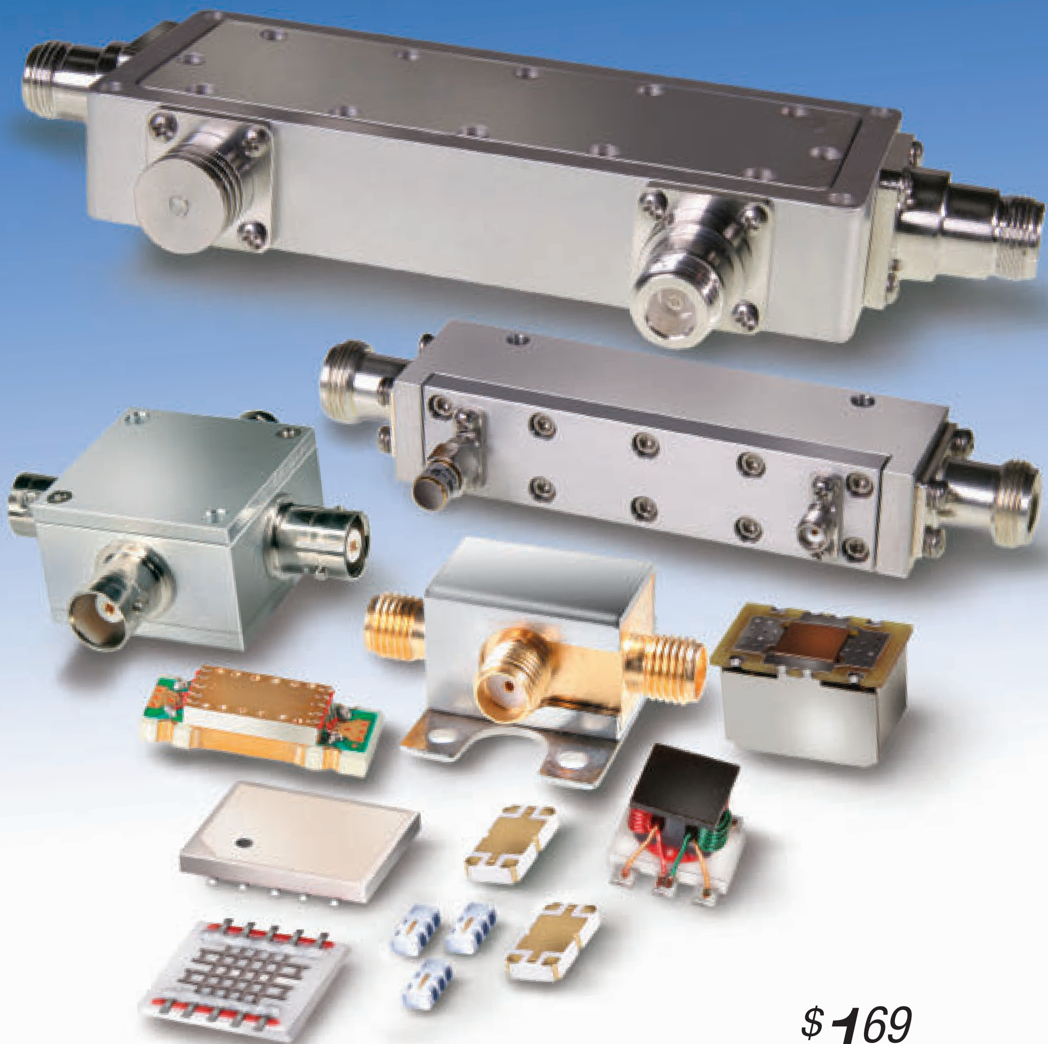

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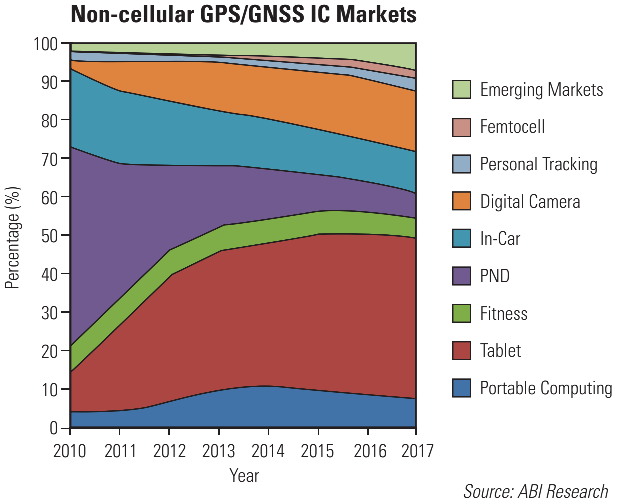
IF/RF MICROWAVE COMPONENTS

GPS/GNSS IC Market on Course to Break $2 B in 2012

The GNSS IC market is showing steady revenue growth in 2012, with the industry now setting its sights on the next major milestone: $3 billion. The smartphone market remains over 70 percent of revenue in 2012, but is an increasingly difficult market for standalone GPS IC vendors. For those that remain, indoor location will be the next major make-or-break technology, while also presenting the potential to generate additional revenue, as illustrated by Qualcomm's IZat platform. However, in the latest edition of its GPS & GNSS Market Data, ABI Research is forecasting that, as the overall GNSS market continues to grow, cellular will become less important, declining to approximately 55 percent of revenues in 2017. The reason is the changing landscape of the GNSS market, as new opportunities emerge across a range of portable device markets.

As illustrated, ABI Research is forecasting a major shift in the market mix for GPS ICs, as new markets emerge around tablets, cameras, femtocells, M2M, fitness, and personal tracking and IC vendors become less reliant on the more traditional PND and the in-car markets. This should create opportunities for combo-ICs modules, indoor and software-based implementations. Senior analyst Patrick Connolly commented, "All major vendors are reassessing their design approaches for emerging markets, by U-Blox's acquisition of Fastrax and the recent CSR-Samsung deal." Practice director Dominique Bonte added, "Breaking $2 billion illustrates how valuable the consumer GNSS IC market has become. The year 2013 will bring significant change and opportunities to the market, with new indoor technologies, emerging vertical markets, and competitors."



Source: ABI Research

RF PA Sales for Wireless Infrastructure Should Top $2.4 B

Although 2012 turned out to be an off year for RF power amplifiers and devices for wireless infrastructure, the market still held its own. The current year should be viewed as a breathing space before both segments resume stable and moderate growth after an explosive 2011.

The Asia-Pacific region, including Japan, continues to account for over 75 percent of the RF power semiconductor devices that are sold into the mobile wireless infrastructure segment. According to research director Lance Wilson, "For the foreseeable future the Asia-Pacific region, particularly China, will remain the most important region and focus for RF power amplifiers and high-power RF devices for wireless infrastructure."

Despite the off year, RF power amplifier sales for wireless infrastructure will top $2.4 billion and RF power device sales will be over $600 million. LTE will become an increasingly important factor in both of these businesses even though the rollout has not been as rapid as the industry would like. Nevertheless, it is already worldwide in scope.

"Although LTE has not significantly impacted RF power amplifier and device sales as of yet," says Wilson, "it is going to bolster RF power sales in the wireless infrastructure space from 2012 on."

The continuing overall need for wireless data remains an important driver for the overall market for both RF power amplifiers and RF power devices.

60 GHz Enabled Device Shipments to Exceed 1 Billion Units per Annum

After many years of waiting, 60 GHz technology looks set to emerge from a niche technology to a mass market solution. The main enabler has been the linking of the WiGig Alliance with the Wi-Fi Alliance and the forthcoming ratification of the 802.11ad standard which will encourage more Wi-Fi IC vendors to add 11ad to future tri-band solutions (i.e., 11n/11ac/11ad).

The partnership between Wi-Gig vendor Wilocity and Wi-Fi vendor Qualcomm Atheros to produce tri-band solutions is starting to bear fruit as Dell was the first to announce an ultrabook product with WiGig/802.11ad.

"Market growth is expected to be slow for the next two years with ultrabooks and peripherals being the initial primary market, driven by the need for ultra-fast data transfer for docking and display applications," commented Peter Cooney, wireless connectivity practice director. "Media tablets are expected to be the next market to embrace the technology, primarily for media streaming." These find-

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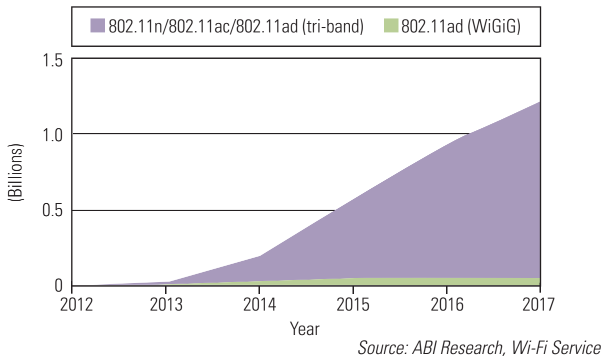
ings come from the new study “60 GHz Technology, 11ad Driving Market Growth,” which is part of ABI Research’s Wi-Fi research service.



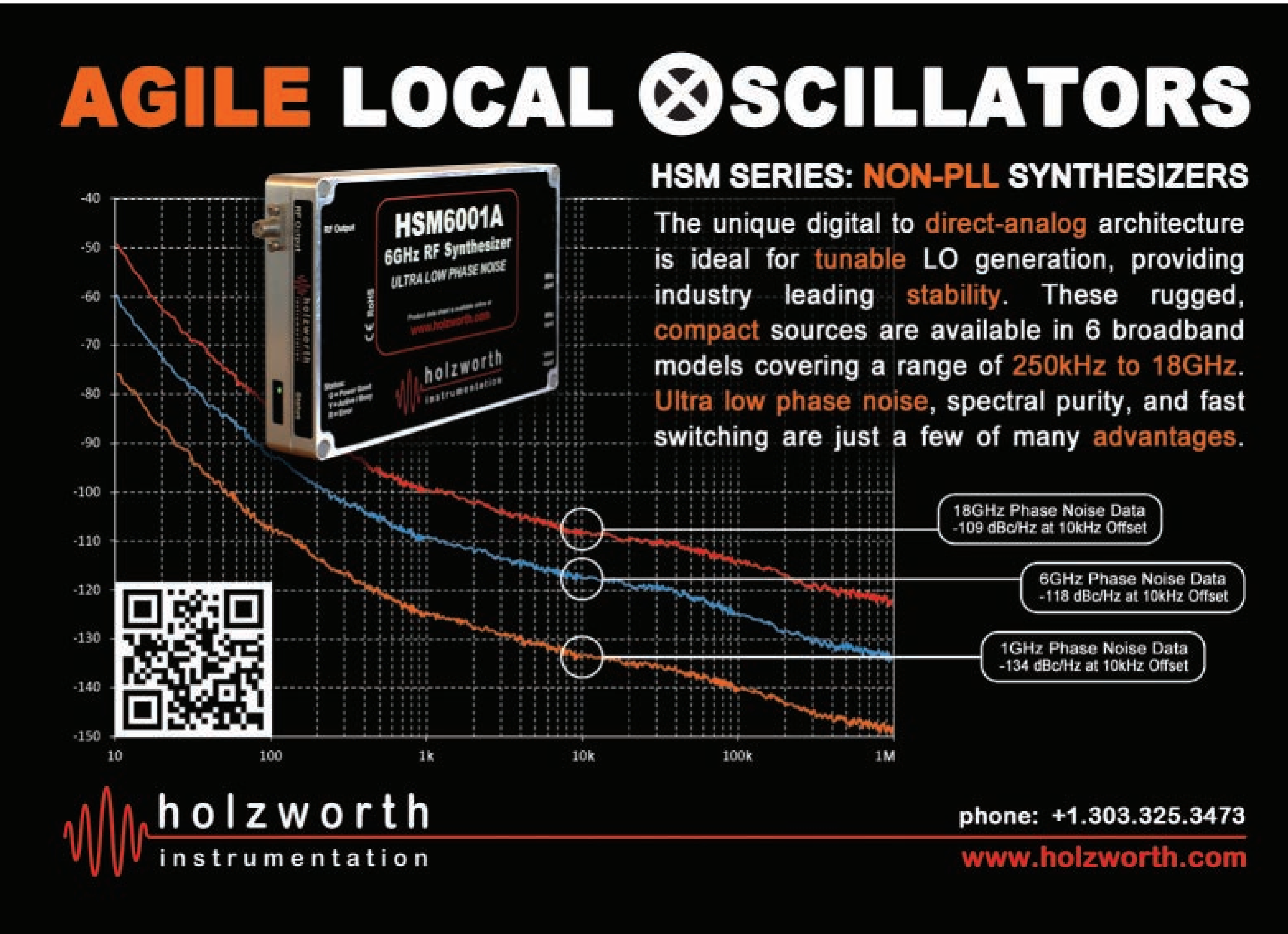
Source: ABI Research, Wi-Fi Service

Mobile Data Roamers to Generate Over $35 B in Revenue by 2017

A new report from Juniper Research forecasts that mobile data roaming revenues will grow by 21 percent per year between 2012 and 2017, reaching over $35 billion in 2017, driven by an increasing number of active data roamers using data services while abroad. However, the report notes that the number of silent data roamers, not actively using any data services, still fear bill shock, as this continues to be markedly higher when compared to silent voice roamers. Silent roamers exercise caution or do not use voice and data services while roaming and represent a non-user segment.

Powered by the proliferation in smartphones and a dramatic growth in data usage, data roaming is being seen as a key growth driver for operators, albeit with cost-effective packages coupled with subscriber control over usage.

The report found that the majority of mobile customers were using voice services when roaming abroad, but this offered network operators little opportunity to add value or enhance services. Data roaming, on the other hand, provided operators with the opportunity to convert ‘non data’ roamers to become active data roamers by the introduction of data bundles and roaming plans. The new report, “Mobile Roaming: Challenges, Opportunities & Market Forecasts 2012-2017,” observed that as data roaming revenues grow and instant messaging apps proliferate, SMS roaming adoption and revenue growth will remain modest, relative to data and voice revenues.



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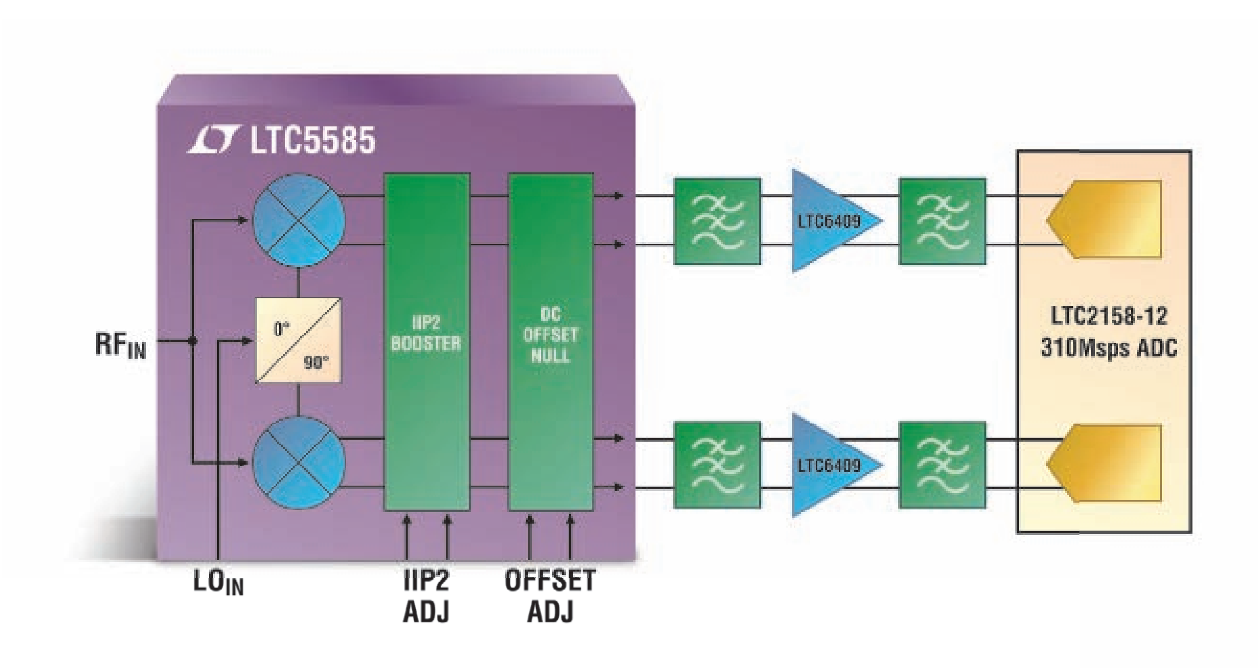

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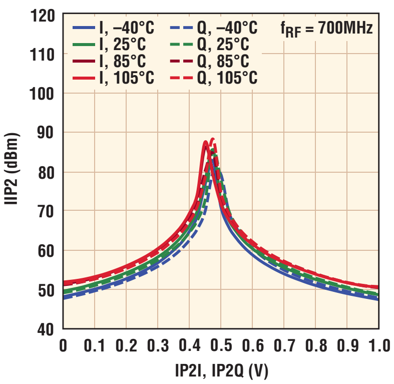
IIP3	31dBm@450MHz	25.7dBm@1.9GHz
Adjustable IIP2	>80dBm	>80dBm
DC Offset Cancellation	Yes	Yes

IIP2 Optimization vs Trim Voltage



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LINEAR TECHNOLOGY

Around the Circuit

Laura Glazer, Staff Editor

INDUSTRY NEWS

National Instruments has acquired **Signalion GmbH** based in Dresden, Germany. The acquisition delivers strong wireless communications talent and technologies to the NI platform, which are critical to NI's goal to continue to drive long term growth in the communications test industry. Signalion founders, Dr. Tim Hentschel and Dr. Thorsten Dräger, will remain with the company as co-managing directors, and work closely with NI R&D to evolve the capabilities of NI LabVIEW system design software and modular PXI hardware for wireless test applications. Signalion will continue to operate as a wholly owned NI subsidiary and to sell and support its products through its direct, distributor and OEM channels.

Carlisle Companies Inc. announced the signing of a definitive agreement to acquire the **Thermax–Raydex** business. The Thermax-Raydex business is a unit of Belden Inc. of St. Louis, MO. The transaction is structured as a purchase of the assets of Thermax and the stock of Raydex/CDT Ltd. both for a combined enterprise value of $265 million. The transaction is subject to customary closing conditions, including regulatory clearance, and is expected to close by December 31, 2012. The acquisition is expected to be accretive to Carlisle in the first year.

NXP Semiconductors and **Audi** have signed a strategic partnership for innovation. The partnership focuses on innovation speed and time to market in eight selected automotive electronics application segments ranging from long-established core leadership positions of NXP's automotive business, such as in-vehicle networking and car entertainment, to emerging technologies for the connected car. This includes Car-to-X communications, telematics, Near Field Communications (NFC), and high-voltage controls for electrical vehicles.

Agilent Technologies Inc. and the **Wireless Institute at the University of Notre Dame** announced that they will establish a collaborative research initiative aimed at developing the next generation of multiple-input, multiple-output wireless technologies. Agilent and researchers at the Wireless Institute have established a core test facility with real-time, broadband signal generation and channel emulation for MIMO wireless systems with up to four transmitter antennas and four receiver antennas.

Rakon and **Symmetricom Inc.** announced that Rakon has joined Symmetricom's SyncWorld Ecosystem Program. Symmetricom has established the SyncWorld Ecosystem Program to enable interoperability and cooperation among vendors who will deliver on service providers' advanced networking requirements.

RFMW Ltd. announced the relocation of its worldwide headquarters in San Jose, CA. "Beyond the additional warehouse space, we'll have more office space for the product management, sales marketing, operations and logistics teams necessary to serve our suppliers and customers for the long term," said Joel Levine, president of RFMW Ltd.

TT electronics expanded its North American operations in Mexicali, Mexico with a new state-of-the-art production facility for the company's portfolio of variable and passive components. The addition of the approximately 68,000 square foot facility, along with a 33 percent expansion of the existing factory, will bring new production lines to the campus, and will allow the company to significantly increase its local employee base during the next year.

Thales Canada announced that its R&D facility in Parc du Technologique is now an official Thales Research and Technology center – the fifth in the world and first in North America. The inauguration of the new facility will strengthen Thales Canada's role beyond development to research, maintaining a leading position with the creation and transfer of technologies. The company hopes the center will bolster the region's innovation network. There will be a strong push to increase research partnerships and work in established research consortia or networks like CRIAQ, PROMPT and GARDN.

Focus Microwaves' first European subsidiary opened in Ottobrunn, Germany, near Munich. The new sales and support office is serving customers throughout Europe, Turkey, Israel and Russia and is headed by Matthias Beer, a former product manager for vector network analyzers from Rohde & Schwarz. Focus Microwaves is now present in three major regions of the world: Europe, Asia and North America.

eesy-ic has opened a new design center in Nuremberg, Germany. The new location should increase the cooperation with the University of Erlangen-Nuremberg to ensure dynamic growth.

Skyworks Solutions Inc. announced that it is powering several smartphone platforms that are leveraging Microsoft's new Windows 8 operating system. With the addition of this latest OS, Skyworks' products are now enabling all major smartphone and tablet operating systems.

7Layers announced that it is the first independent test lab to measure Envelope Correlation Coefficient (ECC). ECC and its measurement is an important parameter to consider when developing an LTE device supporting MIMO antenna systems. 7Layers ability to test and measure the

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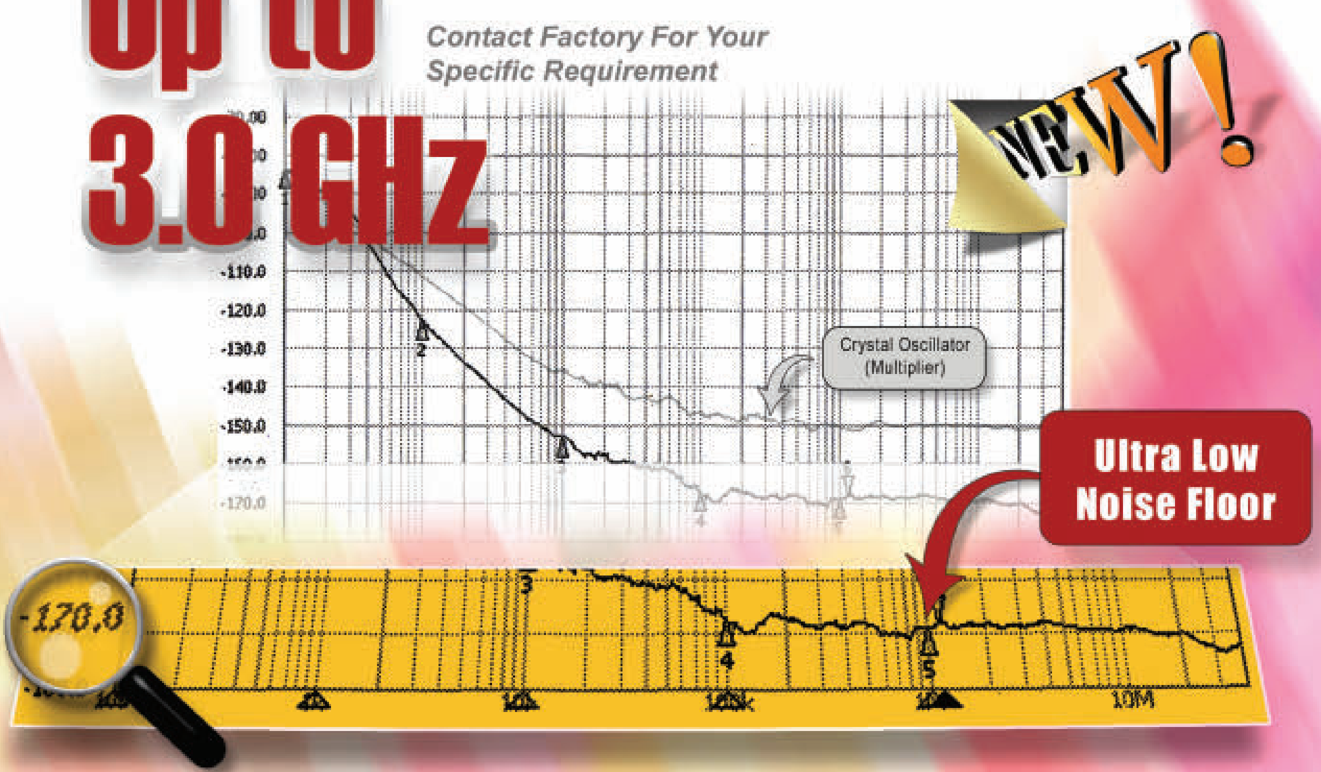

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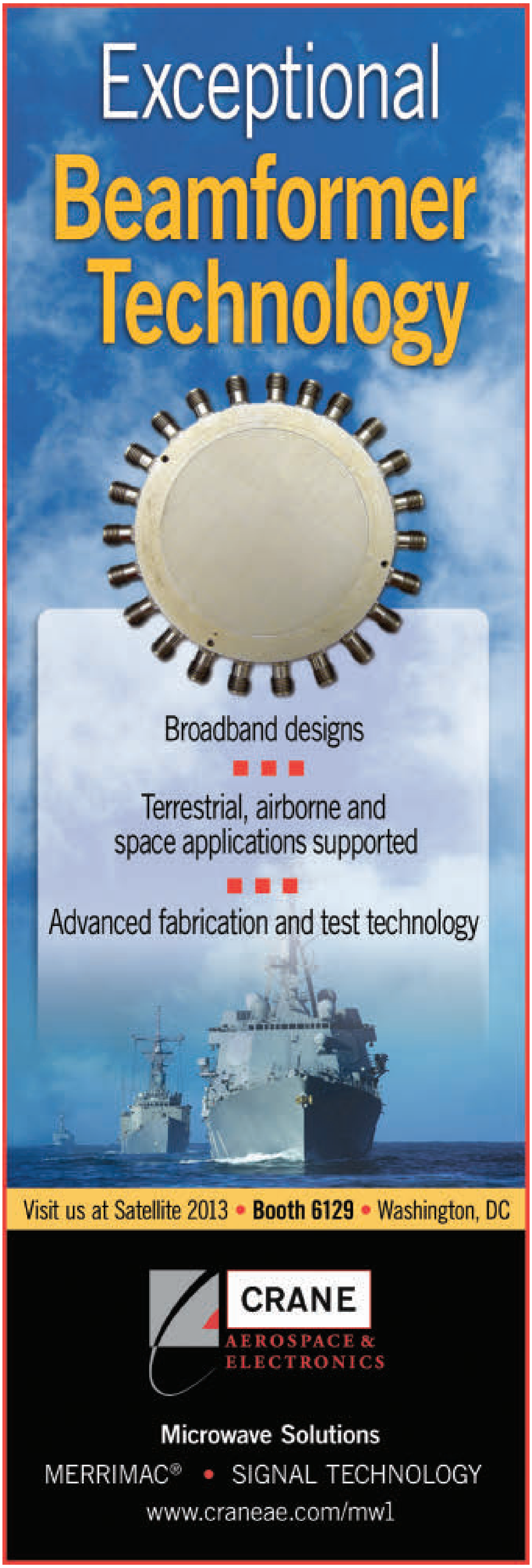

Around the Circuit

ECC represent a major step forward in helping LTE devices reach higher spectral efficiency and achieve faster data rates.

ATW Companies announced that its East Providence, RI-based **Parmatech Corp**. subsidiary has received ISO 9001:2008 certification for its quality management system. The three-year certificate covers the manufacture of powder-injection-molded products for a wide range of industrial applications. Parmatech's Rhode Island facility received the ISO 9001:2008 certification following a rigorous audit conducted by TÜV Rheinland of North America Inc., an accredited third-party registrar.

The Next Generation Mobile Networks (**NGMN**) Board has welcomed the launch of the second LTE Patent Pool managed by SISVEL and combining the patent portfolios of another seven companies. The second LTE patent pool launched by SISVEL underlines the importance of patent pools in the mobile industry and stresses the willingness of companies to participate actively in them. With Orange - France Telecom and KPN, two more members of the NGMN Alliance have now joined patent pool activities.

Delta Microwave is proud to have supported the launch of NASA's radiation belt storm probes (RBSP). Delta Microwave GPS filter/amplifiers are used in the United Launch Alliance Atlas V rocket for range safety during launch.

CONTRACTS

ITT Exelis has been awarded an indefinite delivery, indefinite quantity contract from the **U.S. Army** to provide Generation 3 aviation night vision systems, spare parts and accessories. The contract allows Exelis to compete for deliveries of the AN/AVS-6 aviator night vision goggle and spare aviation image intensifiers during a five year period. The contract is valued at up to $217.5 million.

e2v has signed a new multi-year contract with **Accuray Inc.**, based in Sunnyvale, CA, for the supply of compact modulators and magnetrons for its TomoTherapy®Hi-Art® System, used for the treatment of cancer. Worth a minimum of £20 million, the contract covers a five year period for the exclusive supply of magnetrons and a three year period for the supply of compact modulators, both from e2v's RF power division based in Chelmsford, UK.

Ceragon Networks Ltd. announced follow-on orders of more than $6.5 million with **Mozambique Cellular** (mcel) to expand the carrier's microwave network, first established in 2010. Ceragon is extending mcel's backbone network from Beira in central Mozambique to Nampula in the north of the country, as well as upgrading access links nationwide, providing the only broadband connection available for millions of Mozambicans.

AR Modular RF has received a large order from the **U.S. Navy** for its KMW1031KT 20 W, 30 to 512 MHz booster amplifier kit. The portable, lightweight, fully-automatic

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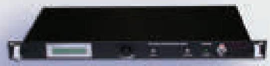

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SM-20M3G-16X16	0.02 - 3.0	16 / 16	16	60	45	100	2.0:1	20
SM-20M3G-32X32	0.02 - 3.0	32 / 32	19	60	45	100	2.0:1	20
SM-2G18G-4X4	2.0 - 18.0	4 / 4	14	60	45	100	2.0:1	20
SM-2G18G-8X8	2.0 - 18.0	8 / 8	16	60	45	100	2.0:1	20
SM-2G18G-16X16	2.0 - 18.0	16 / 16	19	60	45	100	2.0:1	20
SM-2G18G-32X32	2.0 - 18.0	32 / 32	23	60	45	100	2.0:1	20
SM-18G40G-4X4	18.0 - 40.0	4 / 4	16	60	45	100	2.0:1	20
SM-18G40G-8X8	18.0 - 40.0	8 / 8	18	60	45	100	2.0:1	20
SM-18G40G-16X16	18.0 - 40.0	16 / 16	22	60	45	100	2.0:1	20
SM-18G40G-32X32	18.0 - 40.0	32 / 32	25	60	45	100	2.0:1	20

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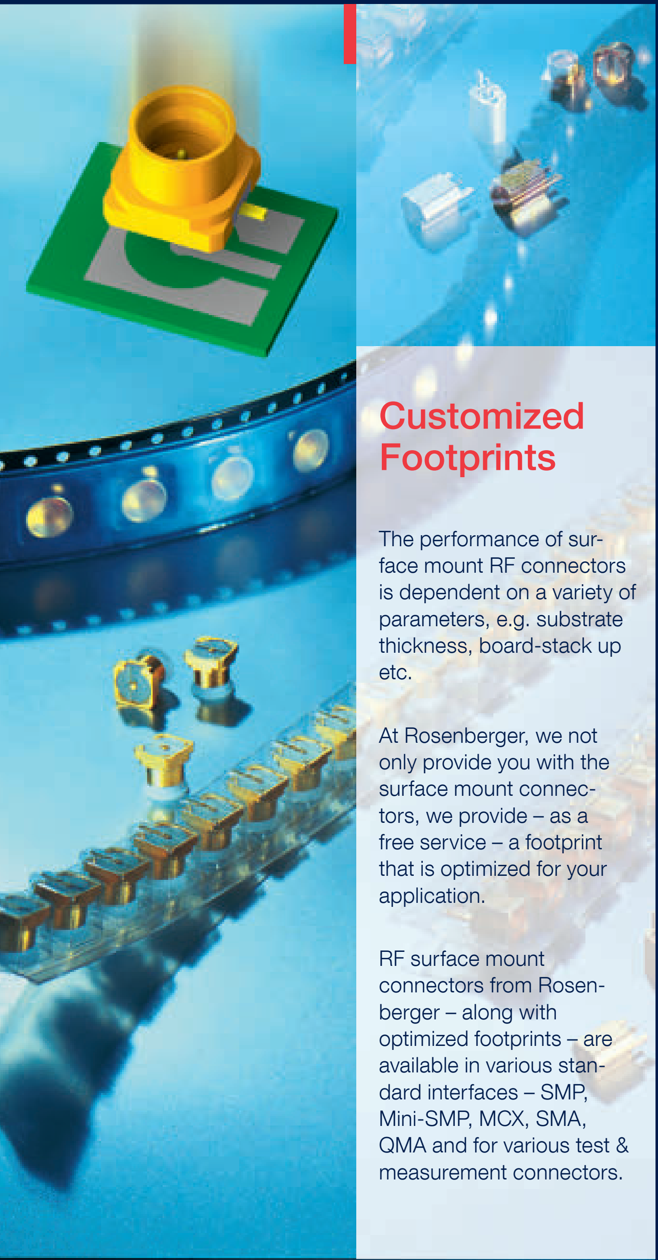

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Cassidian has won a contract to expand the metro coverage of **Beijing Government** Shared Radio Network. The expansion of the TETRA network will improve the network coverage and provide communication and service for Beijing metro police to ensure the security of metro operation. Cassidian will provide 24 TB3 base stations and four TTRX transmitter-receiver units to expand the coverage of the new metro lines. The delivery and implementation will take place in 2013 and 2014.

Cambridge Consultants has been selected by **Iridium Communications Inc.** to play a key role in the deployment of Iridium NEXT, the company's second-generation satellite constellation a significant commercial space program, which is expected to begin launching in early 2015. Cambridge Consultants will spearhead subscriber equipment technology development for the constellation, which will cover the entire globe. It will also provide input into the broader satellite and ground infrastructure system design upon which Iridium NEXT is being built.

PERSONNEL


▲ *Kieran O'Sullivan*

CTS Corp. announced the appointment of **Kieran O'Sullivan** to the position of president and chief executive officer. O'Sullivan brings over twenty-five years of executive leadership experience in high-growth, technology companies. Previously, O'Sullivan was executive vice president of Continental AG's Global Infotainment and Connectivity Business and lead of the NAFTA Interior Division, having joined Continental AG in 2006 as part of the acquisition of Motorola's Automotive Electronics Business.

Mercury Systems Inc. announced the appointment of **Paul Monticciolo** as chief technology officer. Most recently, he served as president and general manager of the company's former Mercury Federal Systems division. Monticciolo joined Mercury Systems in July 2010, when he immediately became involved in critical ISR systems and solutions. Prior to his appointment as CTO, he served as president and general manager of Mercury Federal Systems. Prior to Mercury Systems, Monticciolo held several key positions during his 20-year tenure at MIT's Lincoln Laboratory.


▲ *Paul Monticciolo*

Crane Aerospace & Electronics announced the appointment of **Greg Gomez-Cornejo** as vice president of op-

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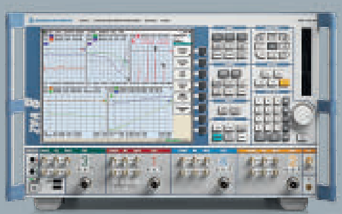

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- Easy-to-use modular solutions up to 500 GHz
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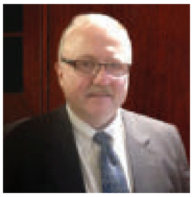
Around the Circuit

erations of the Electronics Group of Crane Aerospace & Electronics. In his role, Gomez-Cornejo is responsible for operations and supply chain for all of Electronics Group locations, including Beverly, MA, Chandler, AZ, Ft. Walton Beach, FL, Redmond, WA, West Caldwell, NJ, Kaohsiung, Taiwan and San Jose, Costa Rica. He will be located in Redmond, WA. Gomez-Cornejo has over 15 years of experience in operations and supply chain.


▲ *Michael J. Sisto*

Michael J. Sisto has joined **Lemko Corp.** as vice president of sales. Sisto has nearly three decades of technology and telecommunications expertise working for IBM, AT&T, Lucent Technologies and Hewlett-Packard. He will spearhead Lemko's sales efforts in the rapidly growing mobile enterprise space. Prior to joining Lemko, Sisto spent 10 years with IBM. Sisto is a senior faculty member at the Keller Graduate School of Management, having taught more than 35 networking and technology courses since 1999.


▲ *Ulrich Jakobus*

Ulrich Jakobus, FEKO product manager and director of **EM Software & Systems–S.A. (Pty) Ltd.** has been named an IEEE Fellow. He is being recognized for leadership in hybrid computational tool development and commercialization. Jakobus' leadership over the past two decades has had a lasting impact on the productivity of electromagnetic applications engineers all over the world. His contributions brought hybrid computational electromagnetic tools to practice and transformed these into FEKO, a successful commercial package.

REP APPOINTMENTS

Laird Technologies Inc. has signed a distribution agreement with **Avnet Abacus** for its Electromagnetic Interference (EMI) and Thermal Management product lines. With this agreement, Avnet Abacus customers in Austria, Germany and Switzerland will have access to Laird Technologies' EMI and Thermal Management solutions.

NuWaves Engineering has added **E.G. Holmes & Associates Inc.** as an authorized representative of its commercial off-the-shelf products and design services for the Southeast region of the U.S.

PEI-Genesis Inc. has been named by **Amphenol Aerospace** as value-added assembler for its micro-miniature 2M connectors.

TotalTemp Technologies Inc. has appointed a sales representative group in the Northern California area, **Semi Test Solutions Inc.** They will be handling product sales for TotalTemp's next generation thermal platform systems (hot/cold plates), temperature controllers and custom engineered solutions.

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AULOS, A Passive Covert Radar System

Passive sensors do not emit electromagnetic waves, but exploit those produced by sources of opportunity (FM radio signals, telecommunications equipment, other radars, etc.). They are therefore compatible with the environment (do not generate additional electromagnetic pollution) and can also operate in close proximity to residential areas and, more specifically, in an urban environment. In addition, passive sensors face the erosion of the electromagnetic spectrum due to the widespread of telecommunications equipment and carry out effectively the surveillance function, not only for the purposes of military defense, but also for homeland security. Furthermore, passive sensors operate in a covert manner and are not subject to electromagnetic interference or intentional threat, surviving where an active sensor may fail its mission.

AULOS, SELEX Sistemi Integrati's new green system, is the result of many years of R&D, some undertaken in concert with the Terrestrial Armaments Department of the Italian Ministry of Defense (MoD). AULOS is a technologically advanced sensor developed entirely on the basis of a "soft radar" approach, involving signal sampling directly at carrier frequency using commercial-off-the-shelf (COTS) devices for signal reception and digital processing. There are plans in the immediate future to develop, in the mobile version, the digital terrestrial television as a ready-made source for use alongside the frequency modulation (FM) radio signal. The resulting bi-band system will offer great flexibility for potential use in a variety of operating conditions and will increase the estimation of the target position.

A passive radar, usually referred to as passive covert radar (PCR) or passive coherent location (PCL), is considered "passive" because it does not have its own transmitter but exploits one or more transmitters of opportunity located somewhere in the countryside. This means that a passive radar does not add a single millijoule to the RF energy already present in the environment. It is a receiving equipment designed to detect and track targets illuminated by one or more broadcast stations, for exam-

R. FULCOLI, M. SEDEHI, E. TILLI AND L. TIMMONERI
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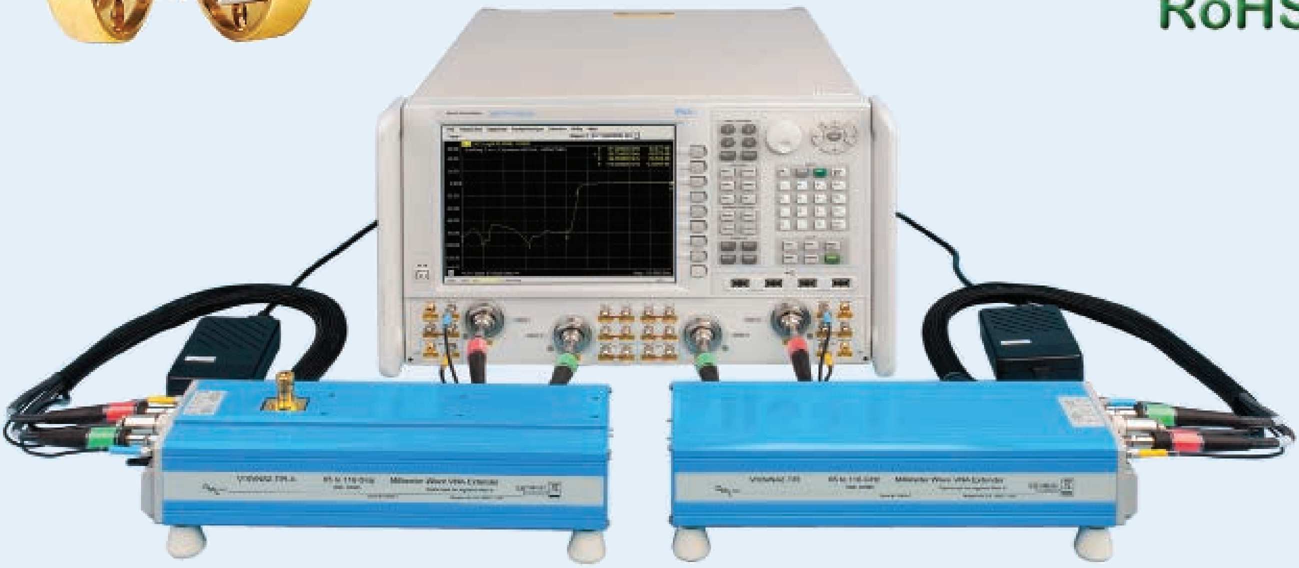

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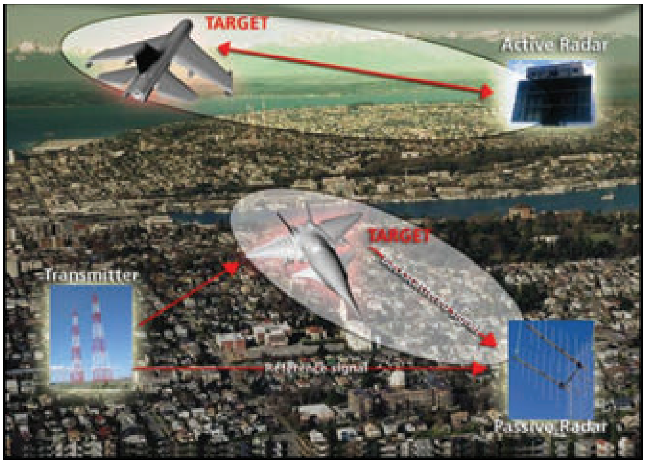

▲ *Fig. 1 Passive radar working principle.*

▲ *Fig. 2 Mobile passive radar developed in SELEX Sistemi Integrati.*

ple, FM radio, digital audio broadcast (DAB), and digital video broadcasting television (DVB-T). ***Figure 1*** depicts the passive radar working principle.

Though the principle of passive radar has been known for decades, it has only recently been of growing interest to research laboratories, universities and industries interested in passive locations. The reason is related to the technology achievements of the last few years, mainly in the field of digital electronics. Today, powerful computers and fast, high-dynamic, digitizers are available on the market for relatively low prices.

Passive sensors may be adopted in a number of applications, most notably for surveillance and environmental protection. Passive sensors may be used to monitor airports, ports, critical infrastructure (for example, power stations and water plants) and information media stations. When it comes to coastal surveillance, passive radars are still expected to offer a number of advantages in terms of eco-compatibility and sustainability. In fact, they can be installed even in protected and previously restricted areas reasonably, without giving either environmental groups or the residential population reason for concern. Moreover, passive radars may be employed as a gap-filler for traditional surveillance systems (for example, coverage beyond 20° elevation) or as an adjunct to air traffic control, particularly for small aircraft without sophisticated instrumentation. It can also be used to monitor commercial and military air traffic up to a distance of several hundred kilometres, and follow targets with very small radar cross-section values compared to normal radar frequencies, when enhanced through the use of FM bandwidth.

SELEX Sistemi Integrati has completed the testing of two prototypes of fixed passive radars operating in the FM band[1-3] and has started the integration activities of a mobile passive radar hosted in a motor home using FM source of opportunity (see ***Figure 2***). The mobile system has been designed to do the following:

- Allow the reception and processing of FM signals (under integration).
- Allow the reception and processing of DVB-T signals[4] for future development.
- Move and deploy an antenna array on a telescopic pole.
- Host comfortably more than one operator.
- Control power supply.
- Host the human machine interface

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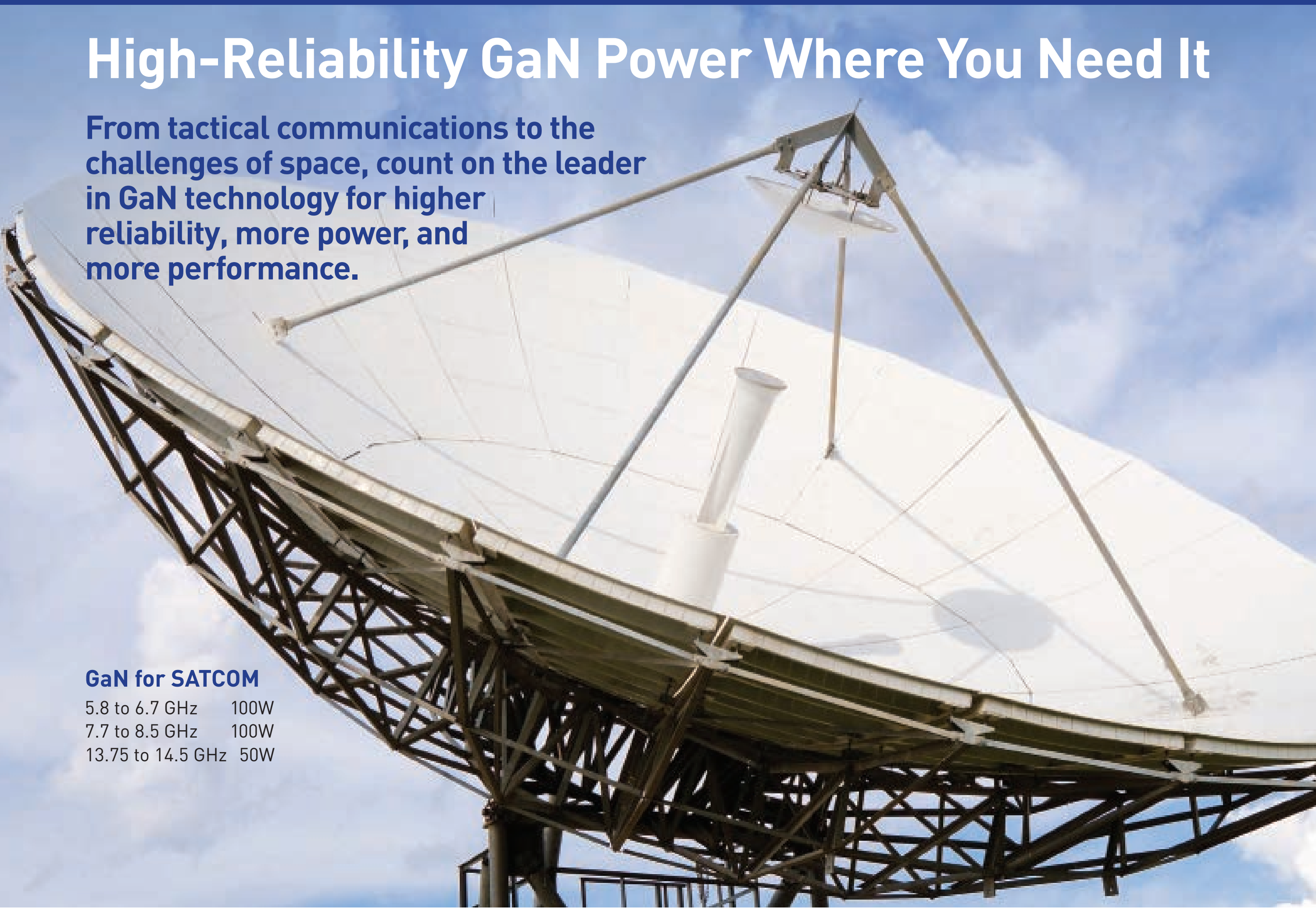

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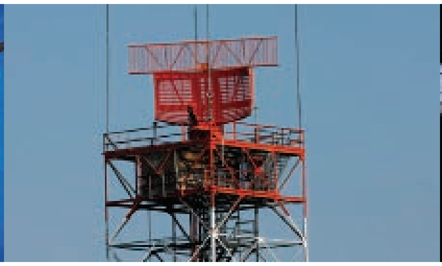

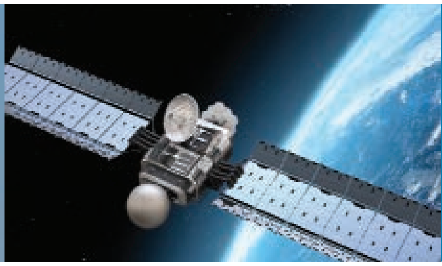

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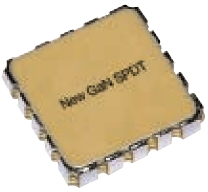

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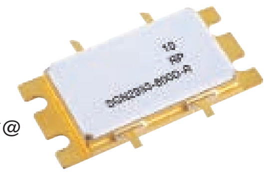

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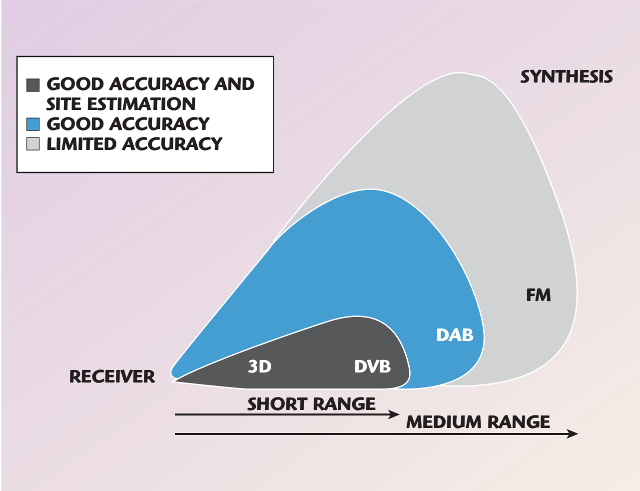

▲ *Fig. 3 Accuracy and detection range of the analyzed frequency bands.*[5]

between the operator and the passive radar.

RATIONALE OF MULTI-BAND DEVELOPMENT

The goal of a radar sensor is to obtain a long detection range, large volumetric coverage (in elevation) and excellent range and angle resolution (related to the instantaneous bandwidth of the signal). To maximize the performance of the passive radar, the following sources have been taken into consideration:

1. FM band
2. DVB-T band
3. DAB band

DAB (190 to 230 MHz) is an international standard for digital broadcasting for mobile reception. DAB allows a channel to distribute multiple radio networks and provides the received signal absolutely free of noise and interference.

Figure 3 shows a simplified volumetric coverage that can be obtained using DVB-T, DAB and FM as a source of opportunity for passive sensors. ***Table 1*** qualitatively synthesizes the expected performance of the passive sensors operating on the different bands.

From the analysis of Figure 3 and Table 1, it is easy to understand the choice to develop a system that combines dual-band characteristics of FM and DVB-T in the future. The resulting sensor will combine the best features of the analyzed frequency bands, thus achieving long-range detection and fine range and angular resolution. Future research items will then be related to a dual band (FM and DVB-T) mobile radar equipped with two circular arrays (uniform circular array [UCA]) having half wavelength dipoles as radiating elements. One of the arrays will be devoted to the FM band and the other to the DVB-T band. The system will be based on a digital beamforming (DBF) technique and it will employ the contemporaneous reception of multiple sources of opportunity.

TABLE I

EXPECTED PERFORMANCE IN DIFFERENT BANDS

Source	Detection Range	Elevation Coverage	Range Resolution	Angular Resolution	Doppler Resolution	Ambiguity Function
FM	++	++	–	–	++	–
DVB-T	–	–	++	++	–	++
DAB	+	+	++	+	–	++

SYSTEM DESIGN DRIVERS

High Level System Requirements

Passive radar deals with weak echoes for detecting small targets, making it necessary to acquire several RF channels using a MIMO receiver with a good trade-off between sensitivity and dynamic range. Direct sampling of the FM band helps to reduce the complexity and the cost of the receiver, but requires a hardware platform able to manage and process the associated high data throughput. In-line (real-time) pre-processing of the signals for implementing multiple digital down conversions (DDC) and fractional resampling helps to select and forward the data associated to the frequency bands of interest to the win SEMICONDUCTORS

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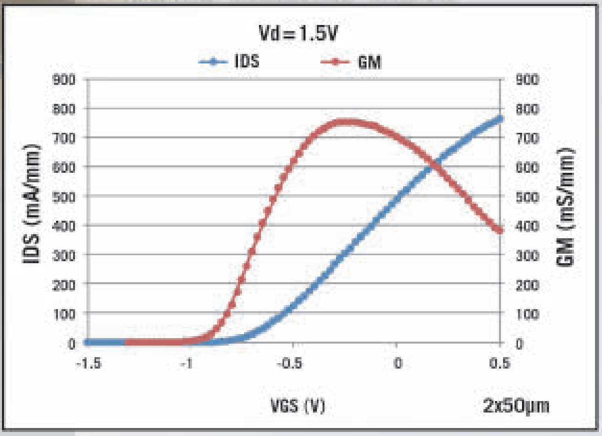
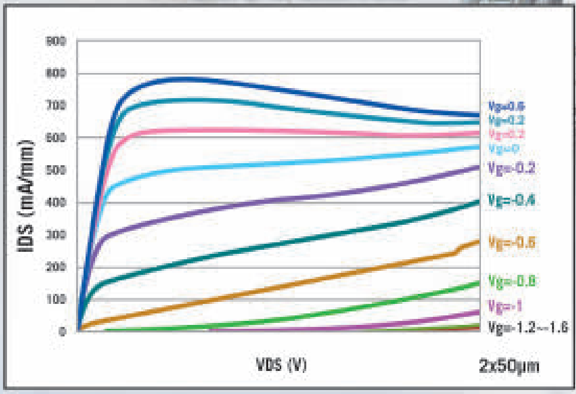
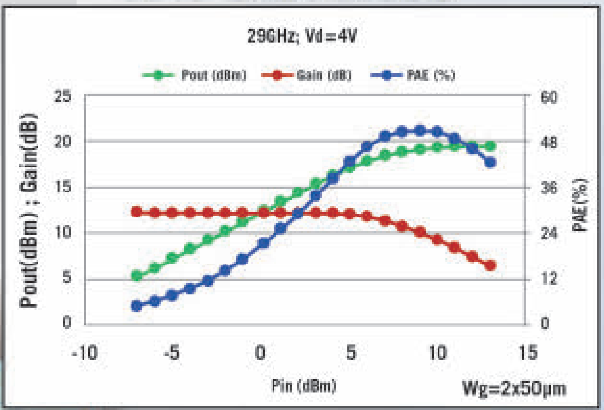


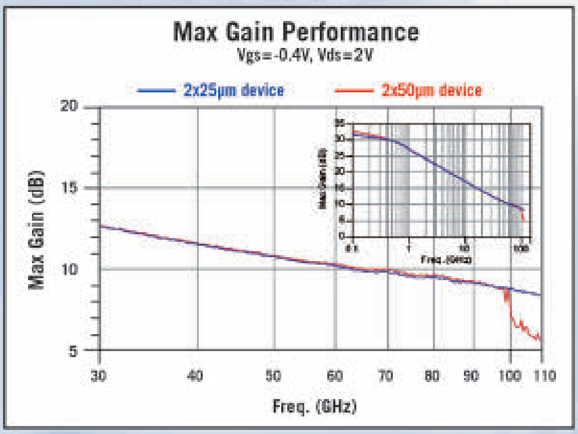
PP10 I-V Curves



PP10 Load Pull Data



PP10 Max Gain



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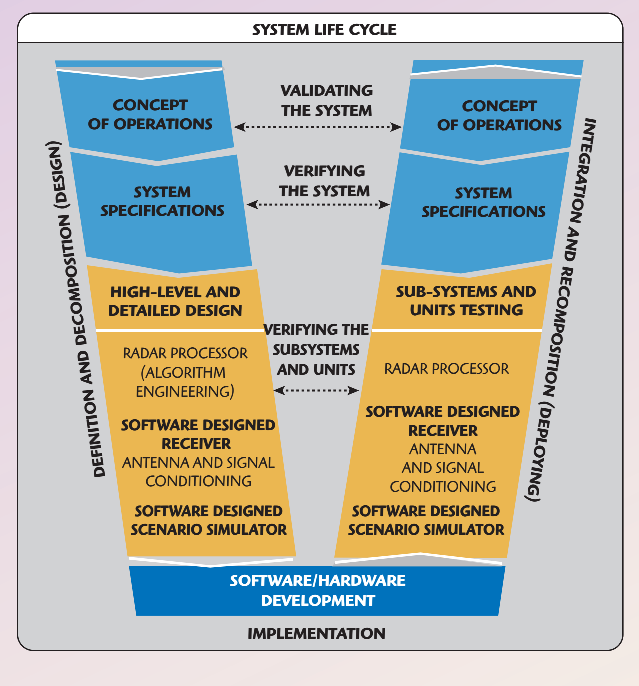
radar processing. The different algorithms used for the pre-processing and the radar processing require heterogeneous processing elements: FPGAs, GPPs and GPUs.

AULOS project has pursued an integrated product and process development (Concurrent Engineering[6]), where the design modularity has made a major contribution to product flexibility and the sharing of the engineering process for designing and testing the radar subsystems and units (see ***Figure 4***). It also accelerated the transition between system life cycle phases because of heavy hardware and software reuse, thereby reducing the total cost and shortening time-to-market.

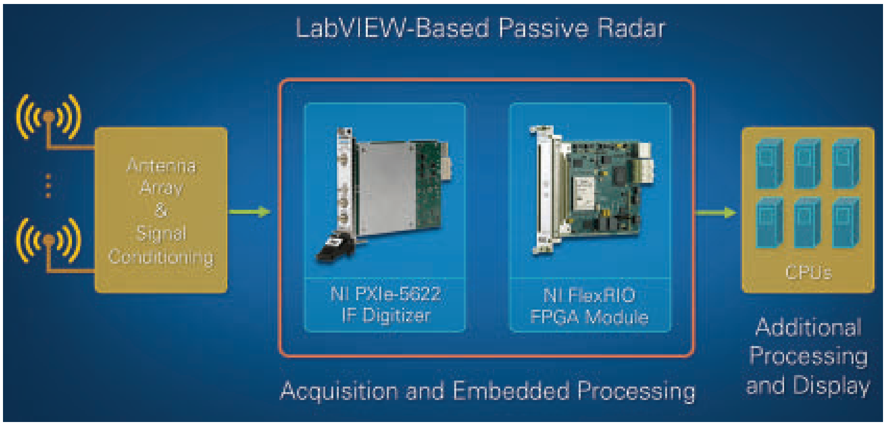


▲ *Fig. 4 Simplified V-model of AULOS.*

Hardware Solution

Not only did the National Instruments (NI) PXI platform meet the adaptability needs of the design, but it delivered the high quality timing and synchronization capabilities required to simultaneously sample the FM stations. Moreover, NI offers a wide selection of PXI RF front ends to cover multiple RF bands and the ability to move the data between all the instrumentation hosted in a chassis at a real-time rate for covering multi-channel acquisition and in-line signal processing by FPGA.

The sampling of the signals coming from the antenna was performed using the high-dynamic range and wideband NI PXIe-5622 high-speed digitizer. Then, thanks to the high data throughput of the PXI Express chassis (more than 800 MB/s per slot), the data was moved to an FPGA for performing the DDC. In this manner, the seamless integration of the digitizer and FPGA provides the software defined receiver (SDR) implementation for AULOS[9,10] (see ***Figure 5***). Finally, the data is transferred to the powerful additional signal processing unit, based on CPU or GPU elements, for implementing the radar processing algorithms to detect very weak echoes from the target that are deeply buried in the noise.



▲ *Fig. 5 Architecture of the software defined receiver.*

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LS0520 P40B	0.5 – 2.0	0.6	1.4:1	+21
LS0540 P40B	0.5 – 4.0	0.8	1.4:1	+21
LS0560 P40B	0.5 – 6.0	1.3	1.5:1	+21
LS05012P40B	0.5 – 12.0	1.7	1.7:1	+21
LS1020 P40B	1.0 – 2.0	0.6	1.4:1	+21
LS1060 P40B	1.0 – 6.0	1.2	1.5:1	+21
LS1012P40B	1.0 – 12.0	1.7	1.7:1	+21
LS2040P40B	2.0 – 4.0	0.7	1.4:1	+20
LS2060P40B	2.0 – 6.0	1.3	1.5:1	+20
LS2080P40B	2.0 – 8.0	1.5	1.6:1	+20
LS4080P40B	4.0 – 8.0	15	1.6:1	+20
LS7012P40B	7.0 – 12.0	1.7	1.7:1	+18

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Note: 2. Typical limiting threshold: +6 dBm.
Note: 3. Power rating derated to 20% @ +125 Deg. C.

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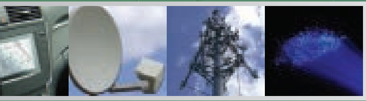

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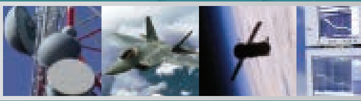

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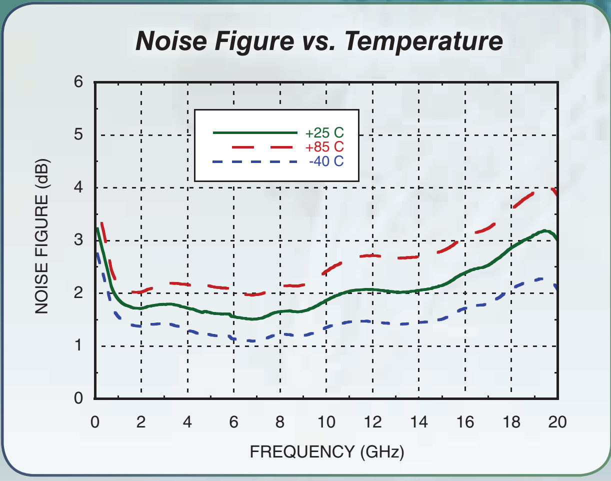

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HMC902LP3E	5 - 10	Low Noise	19	28	1.8	16	+3.5V @ 80mA	LP3
HMC903LP3E	6 - 17	Low Noise	18	25	1.7	14	+3.5V @ 80mA	LP3
HMC963LC4	6 - 26.5	Low Noise	22	18	2.5	10	+3.5V @ 45mA	LC4
HMC564LC4	7 - 14	Low Noise	17	25	1.8	13	+3V @ 51mA	LC4
HMC962LC4	7.5 - 26.5	Low Noise	13	23	2.5	13	+3.5V @ 70mA	LC4
HMC751LC4	17 - 27	Low Noise	25	25	2.2	13	+4V @ 73mA	LC4
HMC519LC4	18 - 31	Low Noise	15	23	3.5	11	+3V @ 75mA	LC4
HMC752LC4 [1]	24 - 28	Low Noise	25	26	2.5	13	+3V @ 70mA	LC4
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HMC-ALH376	35 - 45	Low Noise	16	-	2	6	+4V @ 87mA	Chip
HMC-ALH382 [1]	57 - 65	Low Noise	21	-	4	12	+2.5V @ 64mA	Chip
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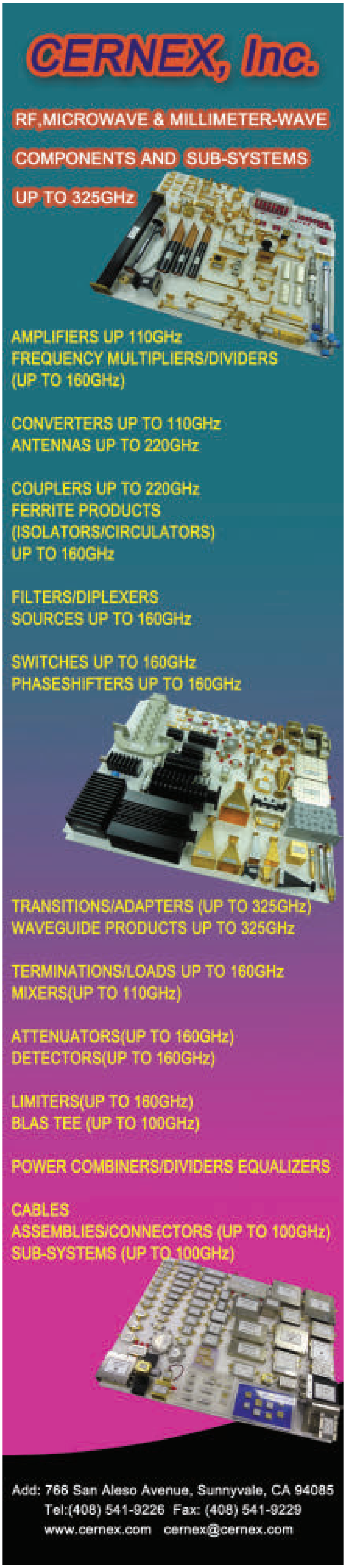

Software Solution

The AULOS project faced a programming challenge for:

1. Implementing an SDR, which deals with multiple acquisition channels and multiple DDCs.
2. Having benefited from heterogeneous computing (GPP, GPU, FPGA) for the complex algorithm implementation.
3. Pursuing an integrated product and process development.

Fig. 6 Hardware platform integration on PXI platform.

Graphical system design methodology, such as the one offered by NI LabVIEW system design software, was one approach for handling this programming challenge. NI's approach to graphical system design helped the project team reuse software and hardware from design to prototyping to deployment of the passive radar system (see ***Figure 6***).

Use of Graphics Processing Unit for Signal and Data Processing

In this section, the work done for mapping the passive radar signal and data processing on GPU-based devices is briefly reported. M. Bernaschi et al. provides many more details on the subject.[7,8] The total amount of data received by a typical processor of a passive radar can vary between 0.5 and 1 Gbit/s, depending on the number of sources and the desired time for processing. This huge amount of data must be handled in real time, possibly using the most compact and least energy consuming hardware system available. It has been demonstrated that the combined use of GPU and CPU is the best suitable solution for combining performance and power consumption.[8] In fact the following observations were made:

- The use of CPU cores allows the efficient management of flow control and the implementation of mainly serial pieces of code.
- The use of GPU cores allows the execution of intrinsic parallel code as fast as possible with low power consumption and frees CPU cores to be used in other tasks.
- The integration of the entire sys-

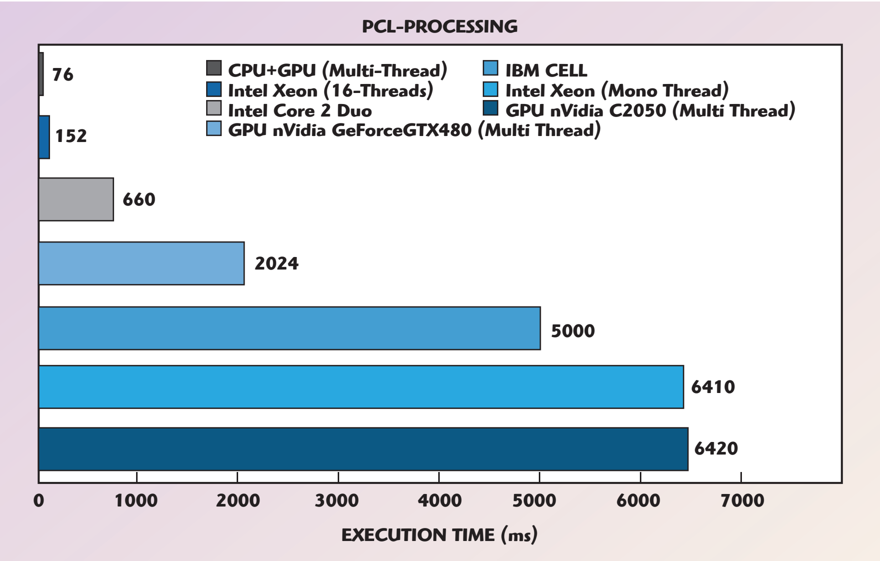

Fig. 7 Comparison among execution time for different implementations of the entire PCL processing.

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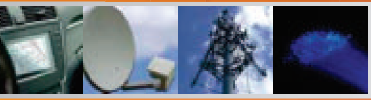

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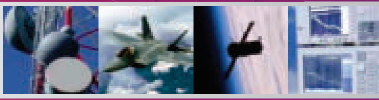

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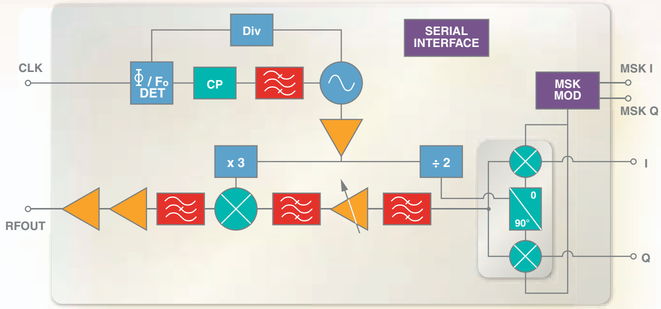
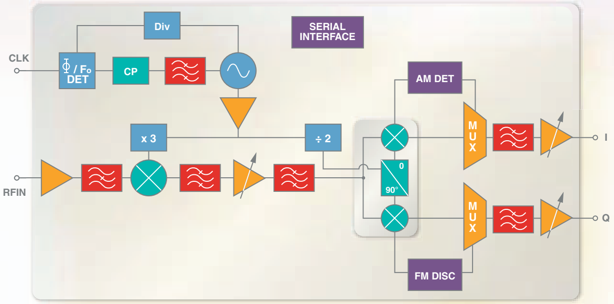


HMC6001 Receiver



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	Frequency (GHz)	Function	Antenna Gain (dBi)	P1dB (dBm)	NF (dB)	Max. Gain (dB)	Gain Adjust (dB)	Phase Noise @ 1 MHz (dBc/Hz)	Power Dissipation (W)	Part Number
	57 to 64	60 GHz Integrated Tx	-	12	-	38	17	-86	0.8	HMC6000
NEW!	57 to 64	60 GHz Tx w/ Integrated Antenna	7.5	11	-	38	17	-86	0.8	HMC6000LP711E
	57 to 64	60 GHz Integrated Rx	-	-	6	67	65	-86	0.6	HMC6001
NEW!	57 to 64	60 GHz Rx w/ Integrated Antenna	7.5	-	7	67	65	-86	0.6	HMC6001LP711E
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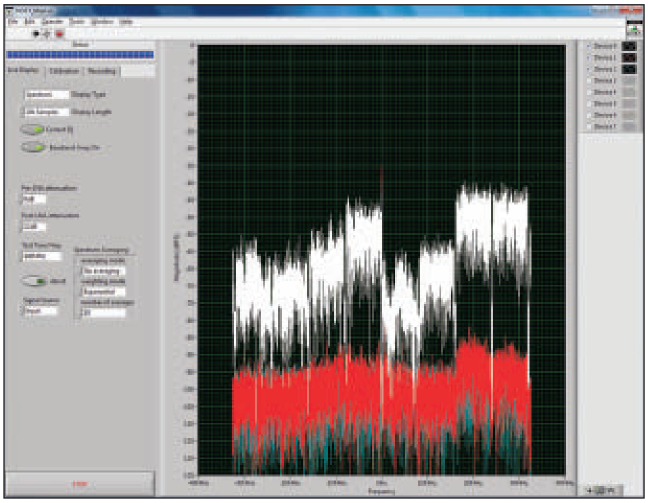
- Power consumption decreases to the minimum.

Figure 7 compares the performance of different computational devices as an example of the achieved results. The execution time of typical PCL processing chains (adaptive interference cancellation, formation of range-Doppler maps and CFAR) has been selected for comparison purpose.

The most convenient approach in the implementation of signal processing for modern PCL systems turns out to coincide with the most common way used nowadays in developing calculus intensive software: the hybrid approach. This kind of approach uses the GPU cores only for the algorithms that can exploit the high parallel computational power of the GPU devices. The CPU, on the other hand, is used for the intrinsically serial algorithms and for all the code that requires a high level of complexity.

CONCLUSION

The current RF signal reception and acquisition technology makes it possible to implement SDR for passive radar detection. Thanks to the wideband and high dynamic range of high speed digitizers, the sampled FM signals are processed using an FPGA that performs the in-line signal channelization. The whole platform was integrated in an NI PXI chassis, delivering a compact form factor for design and deployment in mobile stations. All the critical, real-time software components are implemented in LabVIEW. Also, the technology makes it possible to receive and process multiple channels of DVB-T transmitters providing more accurate target detection and localization (see ***Figure 8***).



▲ *Fig. 8 Spectrum of multiple DVB-T transmitters in the receiver.*

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Spiral Antenna Design Considerations

This article describes a planar spiral antenna structure and its electrical characteristics. To avoid complex mathematical discussions that may be unnecessary for general readers, planar spiral design techniques are described in qualitative rather than quantitative terms. The design discussions appear in progressively important order, so that readers can develop insights into critical reasoning for using or designing spiral antennas. In addition, this article presents limitations of spiral antennas to provide system designers performance tradeoffs when they consider using spiral antennas in their system designs.

The most widely used spiral antenna type is the two-armed planar spiral with metal cavity housing. Other spiral types are usually more complex, uneconomical and unpopular and therefore are not discussed here. For example, a four-armed spiral antenna is much more challenging to build than the two-armed spiral design. Yet, the four-armed spiral's performance may only be slightly better than the two-armed one. Thus the benefits of the four-armed spiral may not warrant the added cost, size and weight of the four-armed spiral.

The two-armed planar spiral antenna, or spiral, has two conductor arms that wind from the center of the spiral to gradually a larger radius in multiple turns. The number of winding turns has the effect of tight or loose spiral structures. The tight spiral tends to have more frequency independent radiation pattern behaviors. The expected effect of the numbers of winding turns has the least impact to overall spiral performance, so long as the spiral is not too loose. Winding turns equal to or greater than three are typically sufficient. Conductor arm shapes are designed such that one arm, when rotated 180°, is the same as the other arm. This guarantees that the spiral structure is rotationally symmetrical, at least across 0° and 180° on a given plane cut.

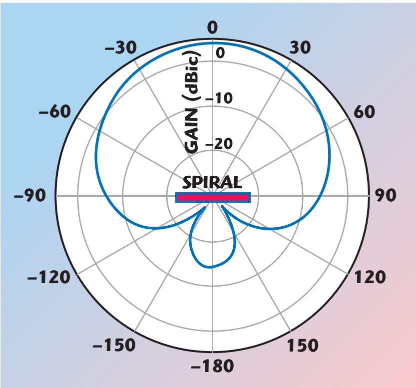

Fig. 1 Typical spiral radiation pattern.

There are two possible radiation modes for a two-armed spiral. Mode 1 is defined as a broad amplitude pattern beam with its peak normal to the spiral plane, shown in ***Figure 1***. Mode 1 phase has a one-cycle phase (hence "Mode 1") from 0° to 360° around the spiral winding. This is the desired radiation mode for most applications. On the other hand, Mode 2 has a split amplitude pattern beam, with a null normal to the spiral plane. Mode 2 phase has a 2:1 phase cycle from 0° to 720° phase around the spiral winding. Mode 2 is rarely used, except in special applications requiring sophisticated beamforming.

It is important to note that the spiral is typically fed by an RF coaxial connector, which has its center conductor unbalanced with its outer conductor. Unbalanced current feeding the spiral can simultaneously excite both Mode 1 and Mode 2 radiation patterns, which is highly undesirable.

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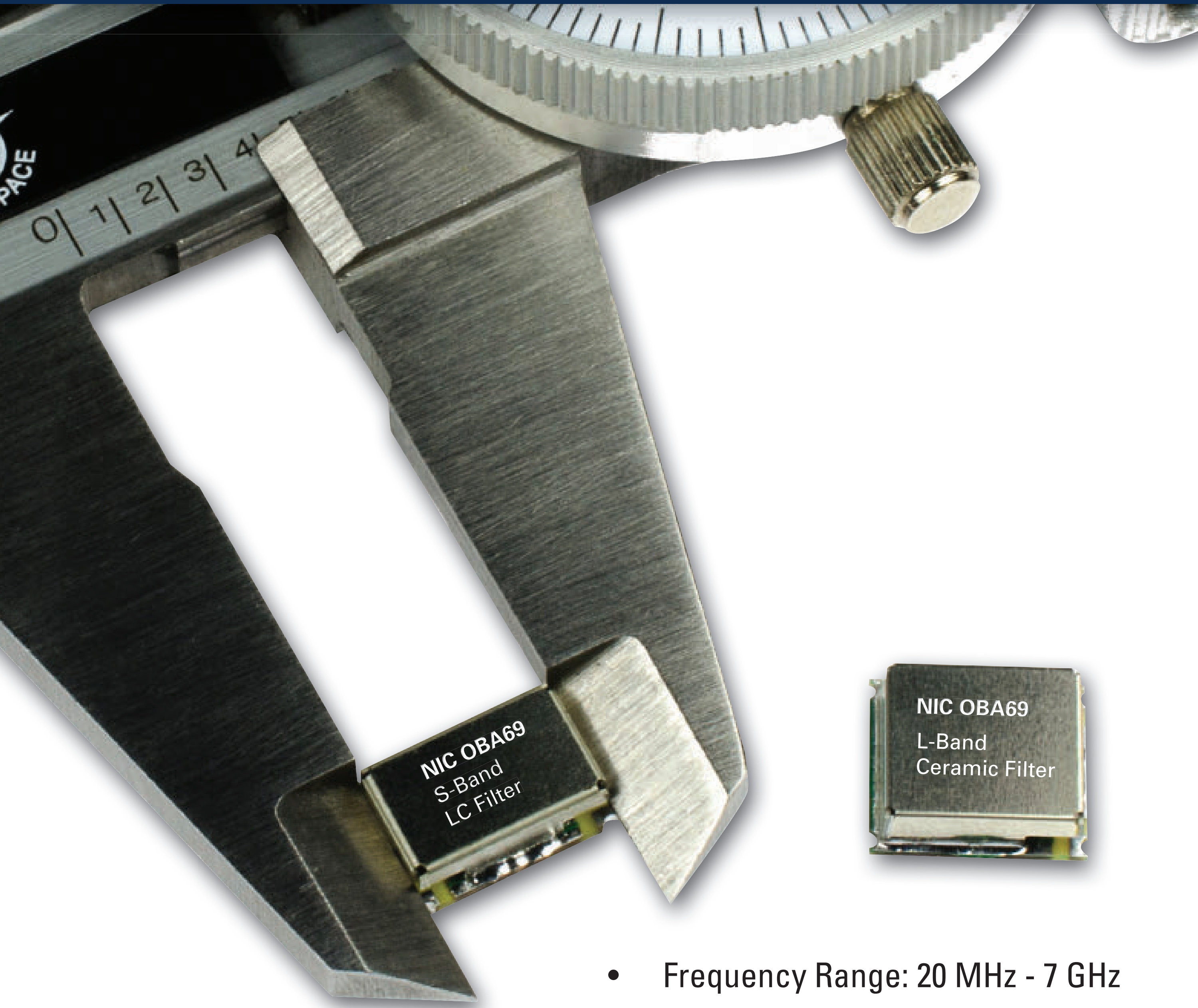

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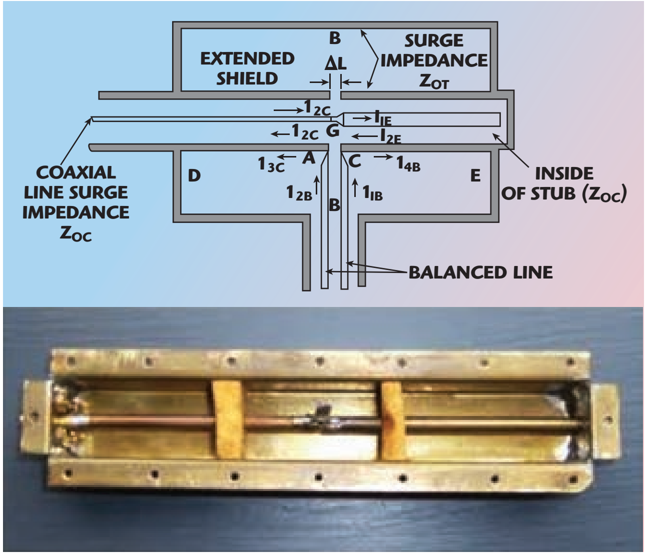
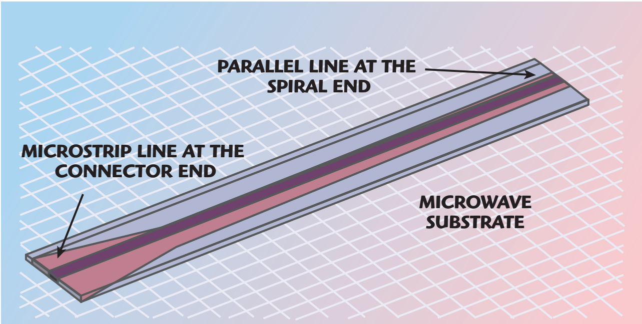


▲ *Fig. 2 Typical Marchand balun (N. Marchand, "Transmission Line Conversion Transformers," Electronics, Vol. 17, Dec. 1944, pp. 142–145).*



▲ *Fig. 3 Typical taper balun.*

BALUN DESIGN FOR SPIRAL ANTENNA

To overcome this, a balun circuit is needed as part of the overall spiral antenna design to convert the unbalanced coaxial mode current to the balanced mode current that connects to the spiral arms in the center.

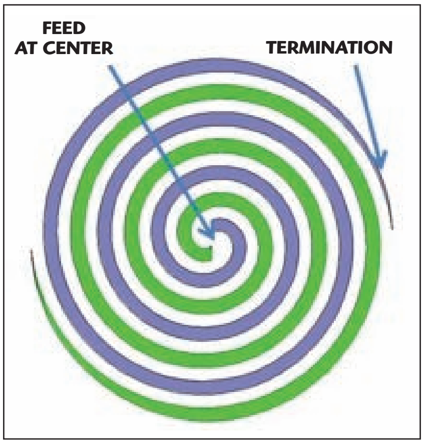
Since the spiral antenna's radiation properties are identical to its reception properties (by reciprocity principles), only spiral radiation is described without loss of generality. If the balun is properly designed, then the spiral radiates the desirable Mode 1 symmetric pattern characteristics in a given azimuth or elevation plane. This is an extremely important performance factor because spiral amplitude patterns are critically used for providing system Angle of Arrival (AoA) performance. However, if the balun is poorly designed, the spiral experiences undesirable performance, such as beam squinting, high axial ratio and pattern nulls. These culprits severely degrade system performance. Therefore, the balun design is one of the most critical elements for a high-performance spiral in an Electronic Warfare (EW) or Electronic Support Measure (ESM) systems. Some commonly used balun designs in the antenna industry are the 10:1 band Marchand balun, shown in ***Figure 2***, and the 40:1 band microstrip taper balun, shown in ***Figure 3***. The Marchand balun is based on RF circuit symmetry, which is consistent with the spiral structure's rotational symmetry. As a result, the Marchand balun is usually the best choice for high-performance spirals, at the expense of some design complexities that lead to higher cost and more weight.

On the other hand, the microstrip taper balun is based on the smooth and gradual transition of an unbalanced mode microstrip line at the connector end to a balanced, equal width parallel strip mode at the spiral center. If the transition length is reasonably sufficient – for instance at least a 3/8 waveguide length – then the taper balun can yield reasonable spiral performance at a much lower cost. The benefit of the taper balun is that low-cost, mass producible printed circuit designs can be realized for high-volume manufacturing.

EQUI-ANGULAR OR ARCHIMEDEAN SPIRALS

The spiral antenna has two common designs; one is the equi-angular spiral and the other is the Archimedean spiral. The equi-angular spiral design, shown in ***Figure 4***, has both the radius and the line-width increasing exponentially with the angles. In this way, the spiral structure is truly self-scalable and self-complementary. Self-scalable means that after the structure dimensions are scaled, the scaled dimensions look exactly like a portion of the original dimension. Self-complementary means that after the two-arm conductors are interchanged with the air space between the arms, the interchanged structure looks exactly like the original structure rotated 90°. This allows near frequency-independent performance. When the frequency changes, the geometry dimensions per wavelength remain nearly the same, thereby preserving the spiral's electrical characteristics.

▲ *Fig. 4 Typical two-armed equi-angular spiral.*



▲ *Fig. 5 Typical two-armed Archimedean spiral.*

On the other hand, the Archimedean spiral, shown in ***Figure 5***, has its radius increasing linearly with angles. Such a radius restricts the line width to be constant with the angles, which avoids short circuiting other parts of the spiral arms. Although the Archimedean spiral geometry is not exactly self-scalable and self-complementary, due to its constant line width, its arm radius is still partially self-scalable and self-complementary. Thus, for all practical purposes, the Archimedean spiral

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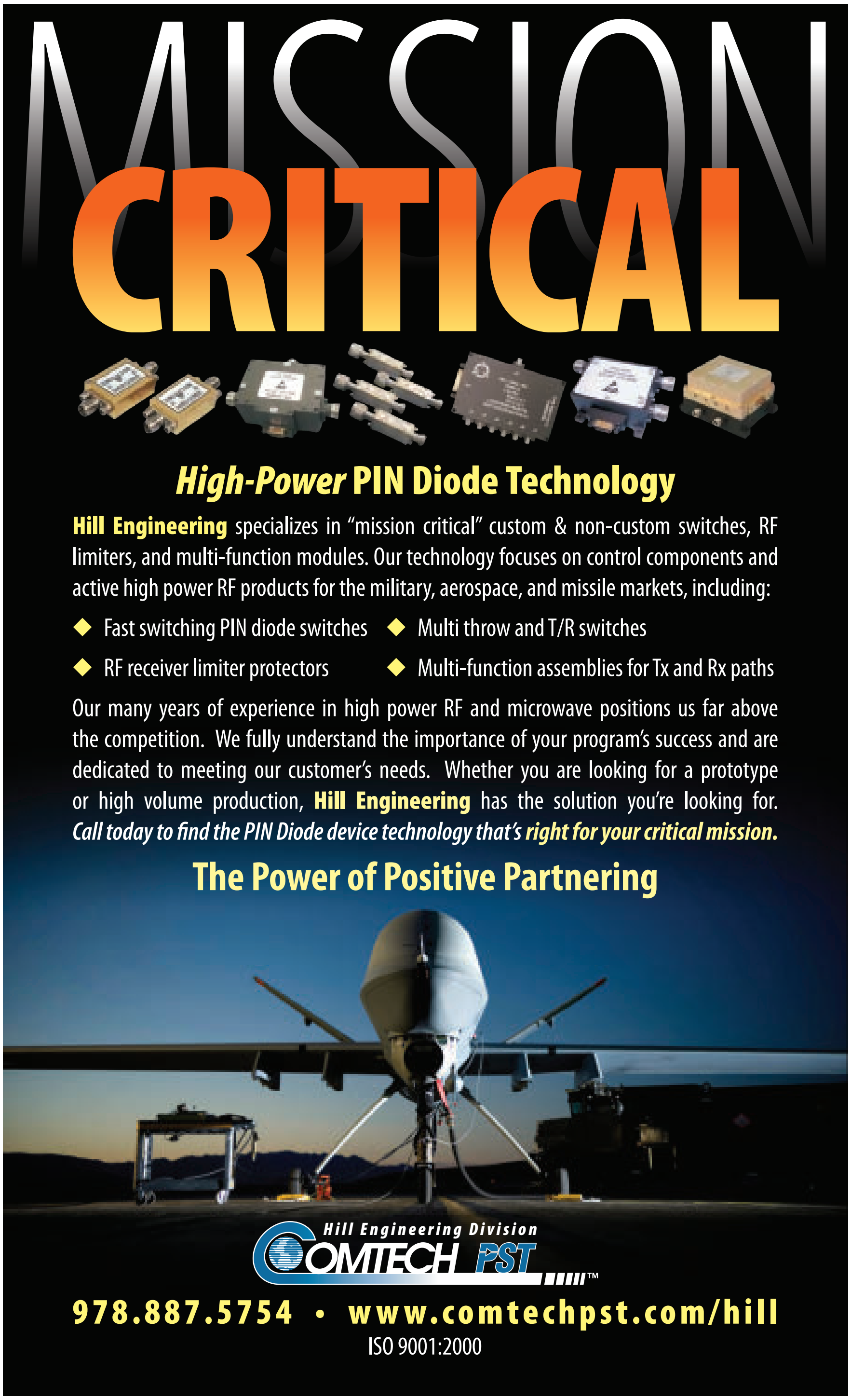
is considered near frequency independent, if the spiral arm line width is sufficiently small. Although the Archimedean spiral performance over fine frequency increments is not as uniform as the equi-angular spiral, this is usually not a serious problem. This is because modern EW or ESM systems typically allow antenna calibration at fine frequency increments to overcome such frequency variations.

ACTIVE REGION

Any practical antenna must have a finite size to meet certain system size requirements. As mentioned, the spiral arm radius increases with angles. At some radius, this spiral arm must be truncated. This truncation sets the low-frequency limit for the spiral performance. As a result, this truncation becomes a very important design parameter.



As mentioned, the balun feeding the two spiral arms at the spiral center is a balanced current pair – one arm is 180° out of phase with the other arm. According to Burdine's radiation band theory, little or no radiation takes place for this pair of balanced currents at or near the spiral center. However, as the spiral arm increases, the differential phase between two adjacent arms progressively deviates from 180°. At some point along the spiral arm, significant radiation takes place, where the phase deviation approaches 0°. In other words, the adjacent currents at this location are in phase. This is the so-called "Active Region" where the spiral currents are free to radiate without counter-restricting each other. Conversely, where the current is balanced along the arms before approaching the active region, such as at or near the spiral center, little radiation takes place. This is the so-called "Inactive Region." From simple geometry calculations, the active region is where the spiral circumference is one wavelength (one λ long).

TRUNCATION EFFECTS

The truncation of the spiral arm inherently excites reflection currents at the truncation end of the arm. These reflection currents travel in the opposite direction toward the spiral center and thereby radiate with the opposite sense of circular polarization (CP). When this opposite sense CP radiation combines with the normal sense CP radiation, the spiral's axial ratio performance will be severely degraded.

To compensate for such truncation effects, designers use a larger spiral diameter, typically 20 percent more, to move the active region away from the truncation ends. The current loses most of its amplitude (that is RF power) to the far field after the active region and only little RF power remains at the truncation. As a result, little reflection takes place at the truncation, as if the truncation is not there. The following formula shows the minimum diameter size for designing a spiral antenna:

$$\text{Diameter} = (1.2)\left(\frac{c}{\text{Flow}}\right)\left(\frac{1}{\pi}\right)$$

c = speed of light

Flow = lowest operating frequency

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The second most important design parameter is to ensure the spiral circumference is at least one λ at the lowest frequency.

ABSORPTIVE TERMINATION

When size is a constraint – such as tight array spacing in a broadband interferometer system for ambiguity rejection at the highest frequency – designers may not have the luxury to choose the spiral diameter using the given equation for lowest frequency. In this case, some termination techniques are needed to reduce the reflection current for the undersized spirals.

One simple way to terminate the spiral is to put absorptive RF materials on the spiral's outer few rings. As current passes through the added absorptive materials, some of the current's RF power is absorbed and most of the RF power still radiates into the far field. This is a very effective technique for maintaining the spiral's axial ratio and input impedance performance, at the expense of slightly lower gain efficiency. The typical gain efficiency loss is on the order of one to two dB, which may be a reasonable compromise between size and performance. Some designers use RF chip resistors as absorptive termination. Resistance values from 120 to 200 Ω are typical, depending on the actual spiral line width to line spacing ratio.

REACTIVE TERMINATION

Another technique is to use less-absorptive dielectric loading materials to slow the current's traveling speed, which is called reactive termination. Some less-absorptive dielectric materials can be added on the outer few rings of the spiral. As current passes through these dielectric materials, the spiral effectively appears electrically larger. As a result, this mitigates truncation effects. This technique is less effective because too much dielectric loading can introduce adverse side effects such as higher order spiral radiation modes, which significantly degrade spiral performance. Some designers use a zigzag spiral as a slow wave structure to avoid added material weight. The effect of this technique may be limited in real-world applications due to self-resonance of such a slow wave structure.

CAVITY HOUSING

A spiral antenna without a cavity housing will radiate in a bi-directional pattern on both sides of the spiral plane. A bi-directional pattern antenna is more sensitive to installation effects such as scattering from the mounting surface. Because of this, uni-directional patterns are more desirable.

One technique to convert a bi-directional to a uni-directional pattern is to use a cavity. Basically, the spiral becomes a probe that excites the cavity. This is similar to how a probe excites a circular waveguide. Typically, the cavity diameter is slightly larger than the spiral diameter. The cavity depth should be at least one quarter wavelength at the lowest frequency if no cavity absorber is used. Due to a constructive reflection from the cavity bottom wall with a quarterwave spacing, this unloaded cavity-backed spiral


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should nominally yield an additional 3 dB more gain than spirals backed by an absorber-loaded cavity. This gain benefit is at the expense of losing frequency independence from the quarterwave spacing. In other words, the unloaded cavity-backed spiral frequency performance is reduced to approximately a 2:1 bandwidth.

In some occasions, designers may need to trade off gain and bandwidth to meet system requirements. Designing absorber loading inside a cavity is considered an engineering art that requires many years of spiral design experience, computer simulations and laboratory testing. This would require a separate article devoted to that topic alone and is not discussed here.

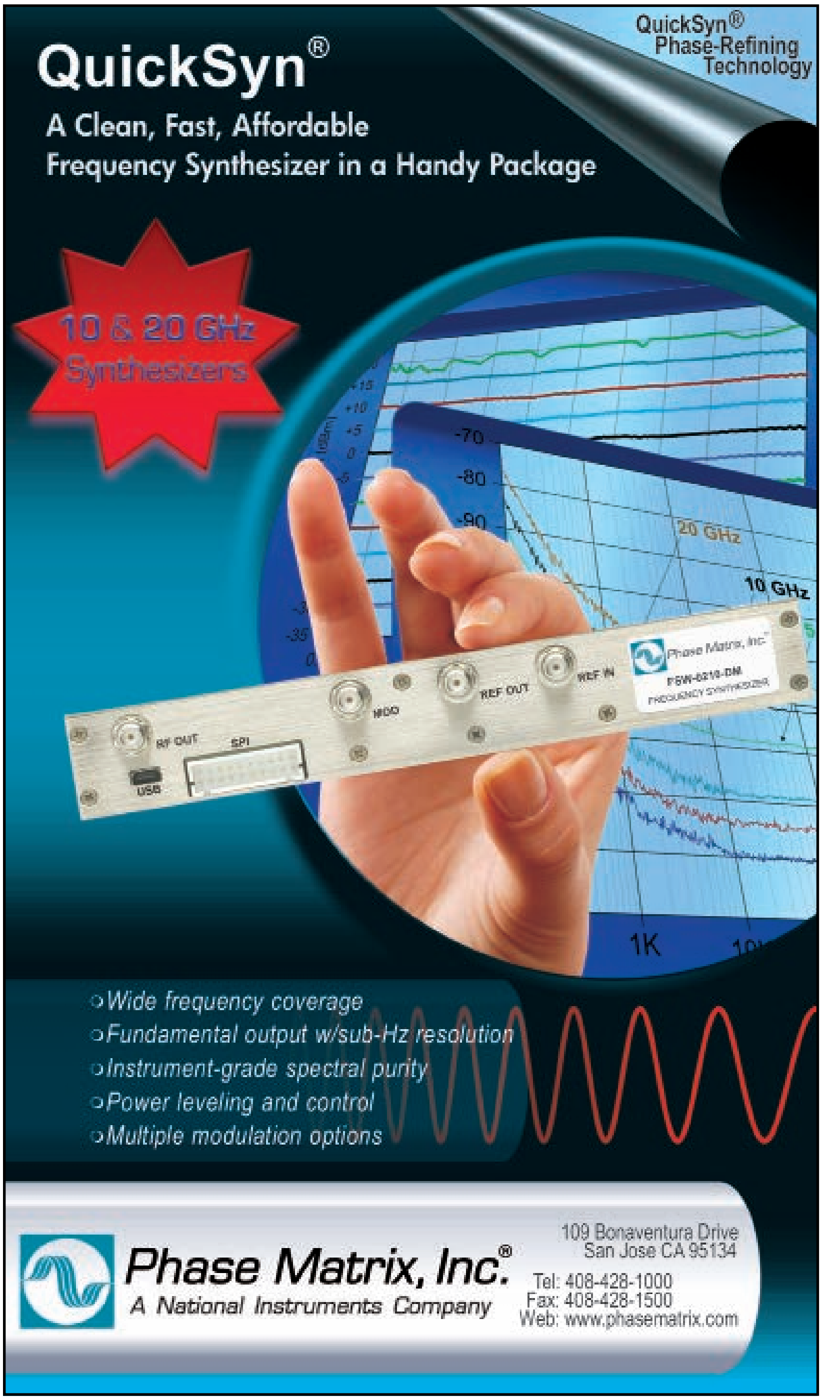
AMPLITUDE AND PHASE TRACKING

An array of multiple spirals with proper translational displacements can be used as a radio frequency (RF) phase interferometer for ESM applications. These spirals typically have phase tracking performance that assures certain system AoA performance. Phase tracking is normally defined as a statistical measure of uniformity of phase over a specified frequency, polarization, azimuth and elevation, compared to a golden standard spiral antenna. A typical measure of statistical uniformity is the root mean square (RMS) of the phase difference between the spiral antenna under test and a golden standard spiral. This is an important performance parameter because the system AoA error is directly correlated with such phase tracking errors, some of which may not be corrected as part of the antenna calibration plan, due to certain system architectures. In other words, high-performance spirals are expected to have superior phase and/or amplitude tracking performance. Typical phase tracking performance is on the order of 6° RMS and amplitude tracking values are on the order of 0.7 dB RMS. To meet such stringent tracking performance, the spiral design needs to be fully optimized, including the spiral structure, balun, cavity, terminations and absorber loading. Any higher-order spiral modes, if excited, could cause serious pattern asymmetry or axial ratio degradation, which could lead to poor tracking performance.

SPIRAL LIMITATIONS

Although spiral antennas have many properties suitable for EW/ESM applications, they have some inherent limitations. One well-known limitation is lower aperture efficiency, hence lower gain for the given aperture size. This is due to the inherent frequency-independent nature of a spiral antenna. As frequency increases, the aperture electrical size proportionally increases. But, because the spiral is a frequency-independent antenna, its gain is unchanged as frequency increases. In other words, unlike a resonant antenna, some of the spiral aperture is wasted when operated in the higher frequency portion of its band.

One limitation of a spiral antenna is its susceptibility to high RF power handling. A good spiral design may be able to handle a few watts average RF power in the Ku frequency band, but is limited due to thermal issues of the currents on the small line width spiral



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arms. In addition, because of the spiral line-to-line spacing along the spiral arms, high field strength arcing can occur if the electric field strength exceeds the air breakdown limit. One mitigation design technique is to use an Archimedean spiral of constant line width near the spiral center. However, this becomes a tradeoff between the line-to-line spacing and high field strength handling. The line-to-line spacing is related to the self-complementary property of the spiral, especially in the higher frequency band. As a result, designers may need to compromise performance at higher frequency with high field strength handling.

Another limitation is off-axis elevation performance. The two-armed spiral, if designed properly, should have good pattern symmetry at 0° elevation. For higher or lower elevations in a conical cut, symmetry starts to deviate due to depolarization effects. This is caused by electric currents on the spiral arms and magnetic currents on the cavity aperture interacting destructively off the principal plane. Design options to mitigate depolarization include: a) Use of as much complementary design as possible to increase rotational symmetry; b) Optimized cavity diameter size to avoid higher order mode excitations; c) Use of four-armed spirals to effectively double the rotational symmetry.

CONCLUSION

The basic spiral antenna design techniques have been reviewed. It has been shown that by use of some understandable engineering principles without complicated mathematics, a spiral antenna can be designed to have reasonable performance. However, spiral antenna design is becoming more challenging due to even smaller size and lighter weight requirements in today's more advanced EW systems. Although spiral antennas have existed over four decades, their design maturity for new requirement challenges, in the authors' opinion, is still evolving. ■

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Rich Bidwell *has been a lead antenna engineer at Lockheed Martin MS2 for over a decade, responsible for E-2C/D and MH60R ESM systems and A10 RF systems. He is the lead engineer for the MS2's Compact Range facility.*

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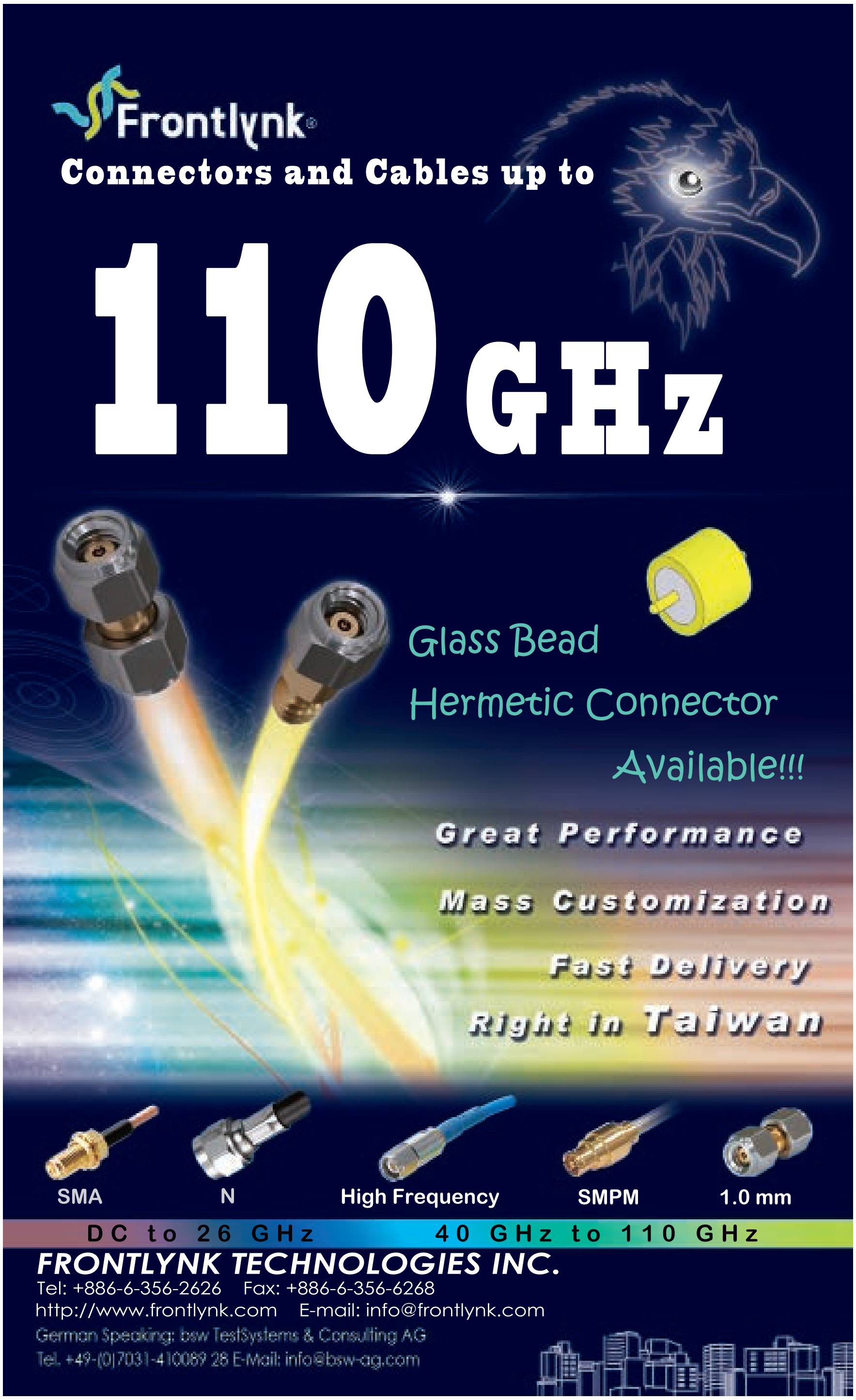

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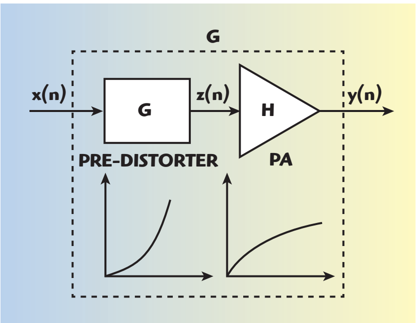
Full Transmitter Linearization Using a Wideband DPD Measurement Platform

Designers transitioning 3G systems to 3.9G and 4G to keep pace with emerging devices like smartphones, face a number of critical obstacles. As an example, consider that signals in advanced wireless communication systems (such as LTE-Advanced and 802.11ac signals) are wideband and have a high peak-to-average power ratio (PAPR), that is, large fluctuations in their signal envelopes. Because of this, the power amplifier (PA) must be backed off well below its maximum ("saturated") output power, in order to handle infrequent peaks, which results in very low efficiencies, typically less than 10 percent. Luckily, power amplifier linearization techniques offer designers one means of increasing power efficiency. One such method, digital pre-distortion (DPD), linearizes the nonlinear response of a PA over an operating region. It uses digital signal processing techniques to condition a baseband signal prior to modulation, up-conversion and amplification by the PA. Using DPD, designers can achieve high efficiency and avoid the severe distortion caused by PA nonlinearities.



▲ *Fig. 1 Pre-distortion system.*

While DPD offers an extremely cost-effective way to accomplish linearization, its use often requires a highly specialized skill set for modeling and implementation. Moreover, the traditional means of extracting a DPD model requires the PA to be turned ON and OFF, when switching to accurately capture PA input and output. Additionally, it supports PA DPD verification only. For linearization of the full RF transmitter, including ADC, filter, amplifier, up-converter and PA, a more novel DPD measurement method is required.

UNDERSTANDING DPD

The principle of a digital pre-distorter, shown in ***Figure 1***, is intrinsically simple. A nonlinear distortion function is built up within a numerical or digital domain that is the inverse of the distortion function exhibited by the amplifier. The predistorter (PD) is designed for some linearization criteria — typically, the suppression of adjacent channel power — while also working to minimize power consumption. Because the PD must be as good an inverse of the PA response function as necessary and compensate for PA deficiencies like nonlinearity, memory effects and gain drift, its design requires good knowledge of the PA's behavior. The PD-PA cascade attempts to combine two

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MLPNC-7102-SMT680	21 @ 400 MHz	23 @ 600 MHz	> -8 @ 4 GHz	> -16 @ 12 GHz	> -20 @ 20 GHz
MLPNC-7103-SMA800	21 @ 800 MHz	23 @ 1300 MHz	> -5 @ 6 GHz	> -15 @ 18 GHz	> -20 @ 30 GHz
MLPNC-7103-SMT680	21 @ 800 MHz	23 @ 1300 MHz	> -5 @ 6 GHz	> -15 @ 18 GHz	> -20 @ 30 GHz

* Contact the factory for additional information or for products not covered in the table.

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nonlinear systems into one linear result, which allows the PA to operate closer to saturation.

MEMORY POLYNOMIAL DPD

One popular DPD solution commonly employed by the industry is the memory polynomial DPD. To better understand this algorithm, consider ***Figure 2***, which shows the indirect learning architecture for the digital pre-distorter. The feedback path labeled "Predistorter Training" (block A) has y(n)/G as its input, where G is the intended PA small signal gain and $\hat{z}(n)$ as its output. The actual pre-distorter is an exact copy of the feedback path (copy of A) with x(n) as its input and z(n) as its output. Ideally, y(n) = Gx(n), which renders z(n) = $\hat{z}(n)$ and the error term e(n) = 0. Given y(n) and z(n), this structure enables the parameters of block A to be directly found, yielding the pre-distorter. The algorithm converges when the error energy $||e(n)||^2$ is minimized.

The DPD architecture in the figure illustrates the case where x(n) is the input signal to a pre-distortion unit whose output z(n) feeds the PA to produce output y(n). The most general form of nonlinearity with Q+1-tap memory is described by the Volterra series, which consists of a sum of multidimensional convolutions. In the training branch of the figure, the Volterra series pre-distorter can be described by:

$$z(n) = \sum_{k=1}^{K} Z_k(n) \tag{1}$$

Where

$$z_k(n) = \sum_{M_1=0}^{Q} \cdots \sum_{M_k=0}^{Q} h_k(m_1,\cdots,m_k)\cdot \prod_{l=1}^{k} y(n-m_l) \tag{2}$$

is the k-dimensional convolution of the input with Volterra kernel. This is a generalization of a power series representation with a finite memory of length Q+1. The z(n) also can be written as follows:

$$z(n) = h_0 + \sum_{m_1=0}^{Q} h_i(m_1)\cdot y(n-m_1) + \sum_{m_1=0}^{Q}\sum_{m_2=0}^{n} h_2(m_1,m_2)\cdot y(n-m_1)y(n-m_2)+\cdots \tag{3}$$

A memory polynomial pre-distorter uses the diagonal kernels of the Volterra series and can be viewed as a generalization of the Hammerstein pre-distorter. It is used to linearize PAs with memory effects. The memory polynomial pre-distorter is constructed using the indirect learning architecture, thereby eliminating the need for model assumption and parameter estimation of the PA. Compared to the Hammerstein pre-distorter, the memory polynomial pre-distorter has slightly more terms; however, it is much more robust and its parameters can be easily estimated by way of least-squares.

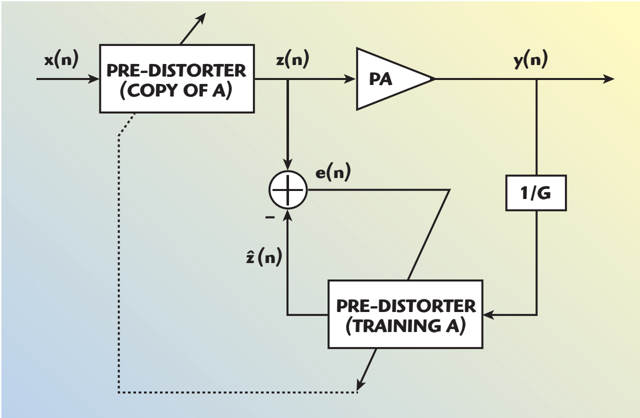

Fig. 2 Indirect learning pre-distortion scheme.

The memory polynomial pre-distorter can be described as:

$$z(n) = \sum_{k=1}^{K}\sum_{q=0}^{Q} a_{kq}\, y(n-q)\left|y(n-q)\right|^{k-1} \tag{4}$$

where y(n) and z(n) are the input and output of the pre-distorter in the training branch, respectively, and a_{kq} denotes the coefficients of the pre-distorter.

Because the model in Equation 4 is linear with respect to its coefficients, the pre-distorter coefficients can be directly obtained using a least-squares approach by defining a new sequence:

$$u_{kq}(n) = \frac{y(n-q)}{G}\left|\frac{y(n-q)}{G}\right|^{k-1} \tag{5}$$

At convergence:

$$z=Ua \tag{6}$$

Where

$$z=\left[z(0),z(1),\cdots,z(N-1)\right]^T,$$

$$U=\left[u_{10},\cdots,u_{K0},\cdots u_{1Q},\cdots u_{KQ}\right],$$

$$u_{kq}=\left[u_{kq},(0),u_{kq}(1),\cdots,u_{kq}(N-1)\right]^T,$$

$$a=\left[a_{10},\cdots,a_{K0},\cdots a_{1Q},\cdots,a_{KQ}\right]^T$$

The least-squares solution for Equation 6 is given by:

$$\hat{a} = \left(U^H U\right)^{-1} U^H z \tag{7}$$

where $(\cdot)^H$ denotes the complex conjugate transpose. Once the memory polynomial coefficients are obtained,

$$\hat{a} = \left[\hat{a}_{10},\cdots,\hat{a}_{K0},\cdots,\hat{a}_{1Q},\cdots\hat{a}_{KQ}\right]^T$$

they can be loaded into the nonlinear filter in the memory polynomial to create a working memory polynomial pre-distorter.

PA DPD VERIFICATION

The behavior of the pre-distorter or device-under-test (DUT) can be experimentally measured using the instantaneous complex baseband waveform approach. This traditional means of extracting a DPD model relies on both PA input and output and needs to switch to capture the necessary PA input and output. Sometimes, the PA must be turned ON and OFF when switching.

A typical setup for this traditional approach is shown in ***Figure 3***. Here, the digital baseband waveform is downloaded to a vector signal generator (VSG) that feeds the PA (that is the DUT) with the corresponding RF modulated signal. The output of the DUT is then down-converted and sampled by a vector signal analyzer (VSA). Finally, the sampled input and output data is captured and used to extract behavioral models (both DPD and PA) for the PA. To accurately observe the behavior of the DUT, the instruments in the setup must have an appropriately large dynamic range and bandwidth.

As shown in ***Figure 4***, the typical design flow for extracting DPD and PA models using both the PA input and output is as follows:

Step 1. The DPD stimulus wave-

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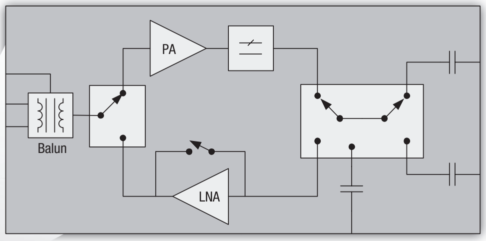

Front-end Module (FEM) Block Diagram

Front-end Modules (FEMs)

Part Number	Function	P_{OUT} (dBm)	Tx Gain (dB)	Rx Gain (dB)	I_{CC} Tx (mA)	Package (mm)	Frequency Band (MHz) < 170	410–470	868–930	2400–2500
SKY66100	Tx / Rx Front-end Module with Rx / Tx Bypass	20–27	30	-0.5	110–300	MCM 4 x 4	•			
SKY65367-11	High Power Tx / Rx Front-end Module with Rx / Tx Bypass	30	35	-0.5	600	MCM 4 x 4	•			
SKY65338	Tx / Rx Front-end Module	27	32	–	315	MCM 8 x 8		•		
SKY65342-11	High Power Tx / Rx Front-end Module with Rx Bypass	29	34	-0.6	650	MCM 8 x 8		•		
SKY65378	Low Power Front-end Module with Tx Bypass and LNA	–	–	14–17	3–7 (1)	QFN 4 x 4			•	
SKY65346-21	Tx / Rx Front-end Module with LNA	26	35	13.7	200	MCM 5 x 5			•	
SKY65313-21	Tx / Rx Front-end Module with LNA	30.5	28	16.6	695	MCM 6 x 6			•	
SKY65364	High Power Tx / Rx Front-end Module with LNA, PA, Tx / Rx Bypass, HD Filter	30.5	30	15	730	MCM 6 x 6			•	
SE2435L	High Power Tx / Rx Front-end Module with LNA	30	28	16	550	QFN 4 x 4			•	
SE2442L	High Power Tx / Rx Front-end Module with Rx Bypass	30	28	-0.7	550	QFN 4 x 4			•	
SE2438T	Low Power Tx / Rx Front-end Module with LNA	10–14	16	12.3	20–33	QFN 3 x 3				•
SE2431L	Tx / Rx Front-end Module with LNA	20	23	12	110	QFN 3 x 4				•
SE2432L	Tx / Rx Front-end Module with LNA	20	22	11.5	110	QFN 3 x 4				•
SE2436L	High Power Tx / Rx Front-end Module with LNA	27	28	11.5	400	QFN 4 x 4				•

1. SKY65378: I_{cc} Rx gain value shown.

Power Amplifiers

Part Number	Function	P_{OUT} (dBm)	Gain (dB)	$P_{1 dB}$ (dBm)	Package (mm)	Frequency Band (MHz) 450	915	2400
SE2433T	2-Stage Power Amplifier	24	22	24	QFN 2.5 x 2			•

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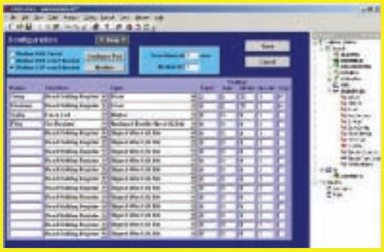

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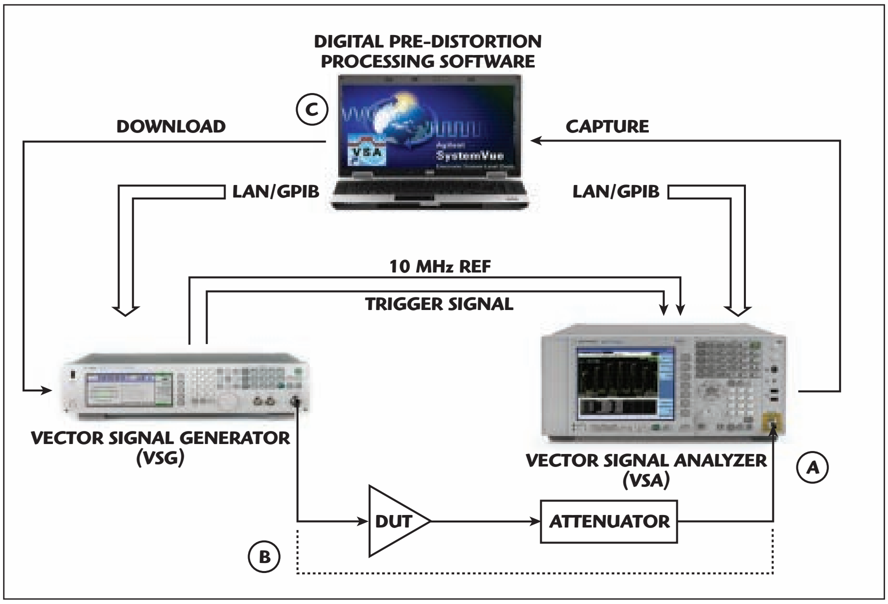


▲ *Fig. 3 Experimental instrument platform for PA and DPD modeling.*

form (that is 802.11ac, LTE/LTE-A, WCDMA, or user defined) is created and downloaded via LAN or GPIB into the VSG.

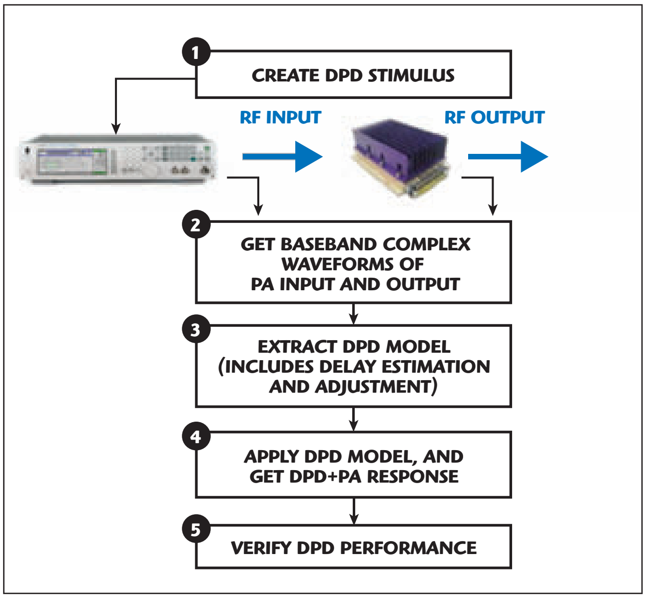
Step 2. The PA's response, both input and output (point B and A in Figure 3), is captured from the VSA running vector signal analysis software. The PA output signal is captured by inserting the PA between the VSG and VSA with appropriate signal calibration, including any signal padding with attenuators.

Step 3. DPD models are extracted based on PA input and output. This includes time delay estimation and adjustment. Note that the propagation delay through the DUT introduces a mismatch between the data samples used to calculate the instantaneous AM/AM and AM/PM characteristics of the DUT. This mismatch translates into dispersion in the AM/AM and AM/PM characteristics, which can be misinterpreted and considered as memory effects.

Step 4. The DPD+PA response is captured by applying stimulus to the extracted DPD model and downloading the DPD output waveform into the VSG. The PA output waveform is then captured from the VSA.

Step 5. The DPD+PA response is verified, and the performance improvements possible with DPD can be shown.

This traditional method is effective in providing DPD with a specific PA; however, it does have some drawbacks. Because it requires switching, for example, the method is complicated. It can also be tiresome and dangerous to continually turn the high power amplifier ON and OFF. The distortion characteristic will be different after each turn OFF and ON, impacting



▲ *Fig. 4 Behavior model extraction procedure with both PA input and output.*

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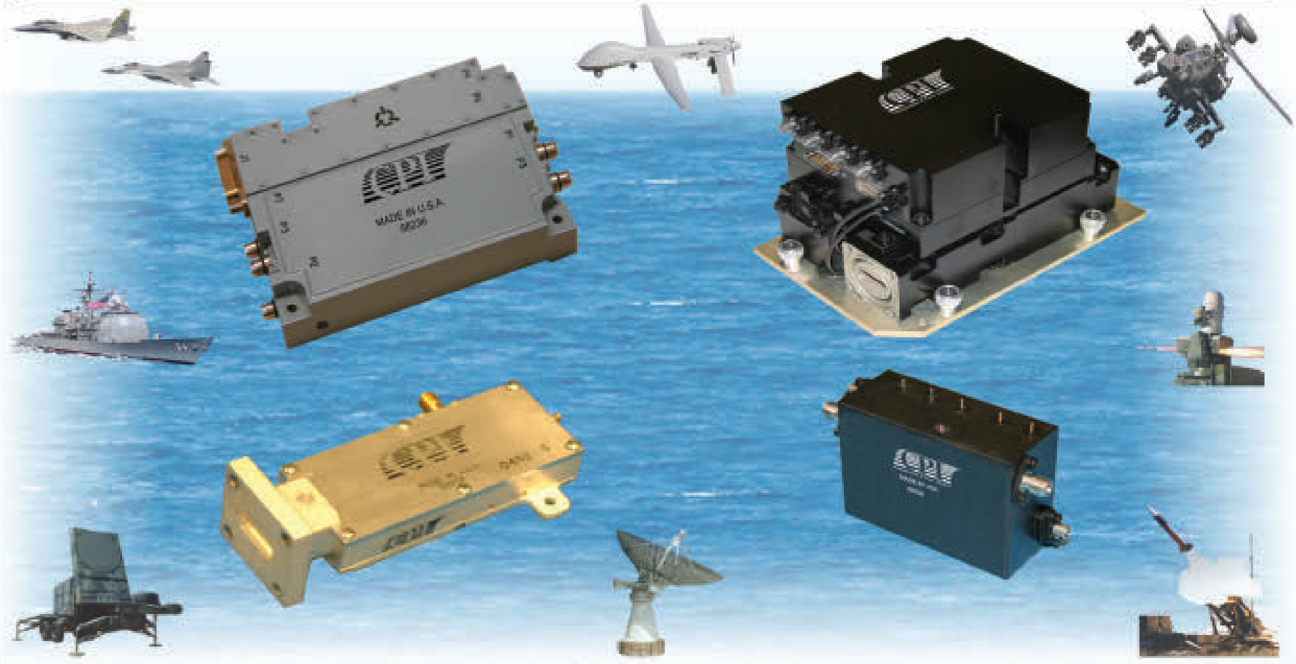

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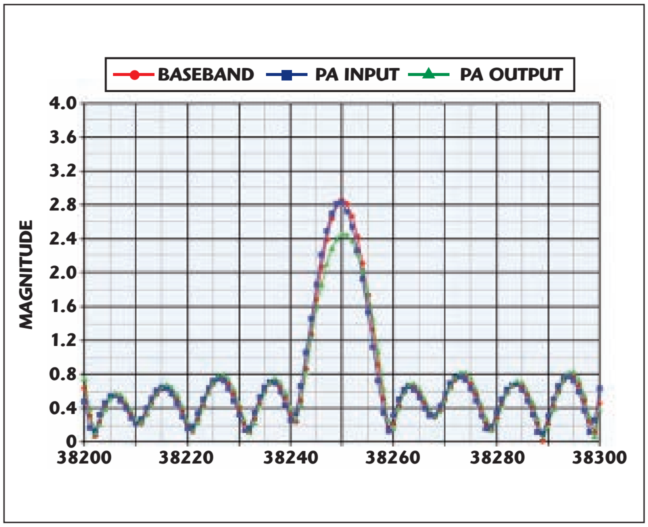
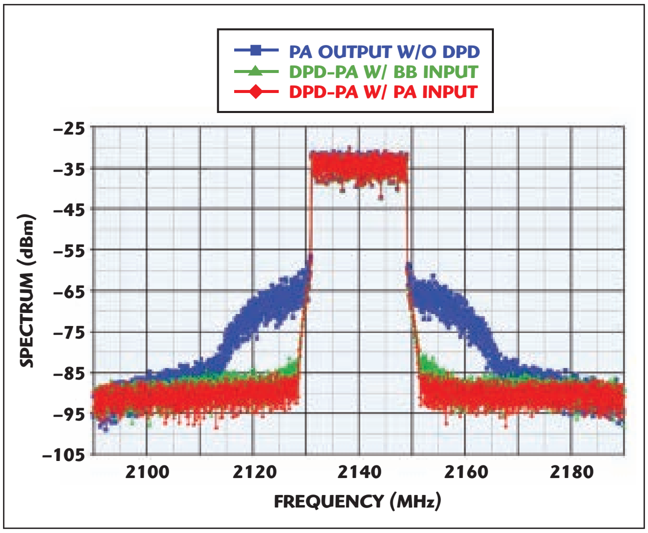


▲ *Fig. 5 Sample time-domain waveform of baseband input, PA input and PA output.*



▲ *Fig. 6 Spectrums of the system with and without DPD.*

both DPD model extraction and DPD performance. Additionally, the method fails to provide a DPD for the full analog circuit board, something that is recommended given that in actual application, the DAC, up-converter, pre-amplifier and PA are all designed on one analog circuit board.

THE FULL RF TRANSMITTER LINEARIZATION METHOD

In contrast to the traditional approach to PA DPD verification previously detailed, DPD models can also be extracted using simulated baseband input and real PA output. In this case, a baseband input waveform replaces the PA input waveform in Figure 3 (that is Point C replaces Point B). Rather than just supporting PA DPD verification, this method provides a DPD verification solution for the full RF transmitter, including ADC, filter, amplifier, up-converter and PA.

The full RF transmitter linearization method follows the steps previously detailed for PA DPD verification with one exception. Additional coarse time-delay estimation performed at the sample level is required in Step 2 to synchronize between the real PA output waveform and the simulated baseband waveform. This is done because a trigger signal is used to capture the arbitrary waveform from the VSA and the baseband waveform, which is the ideal waveform and, therefore, does not have any time-delay. The coarse time delay is estimated according to the cross-covariance between the input and output sequence of the PA as follows:

$$\mathrm{corr}(n) = \sum_{k=1}^{N} X_{BB}(k)\, y^{H}(k-n) \qquad (8)$$

where N is the number of captured samples.

Following the coarse time-delay estimation, a fine time-delay estimation is carried out by placing a higher interpolation rate between the PA output and baseband waveform. This fine time-delay estimation is the same as the algorithm used between the PA output and input waveforms.

This method for full RF transmitter linearization can correctly extract a DPD model for the VSA, pre-am-

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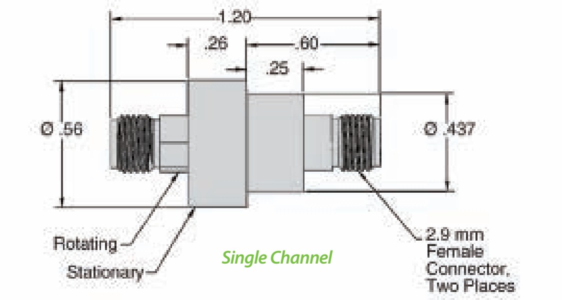

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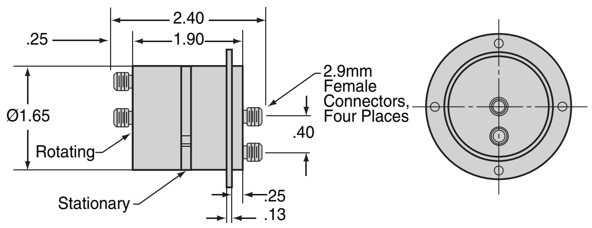

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	10 - 26 GHz	1.35 : 1 MAX.
	26 - 40 GHz	1.75 : 1 MAX.
WOW	1.05 MAX.	
INSERTION LOSS	DC - 10 GHz	0.2 dB MAX.
	10 - 26 GHz	0.4 dB MAX.
	26 - 40 GHz	0.6 dB MAX.
PEAK POWER	Equal to connector rating	

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ELECTRICAL	Channel 1	Channel 2
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WOW	0.15	0.25
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TABLE I

ACLR OF THE SYSTEM WITH DPD OF MODEL EXTRACTION USING BOTH PA INPUT AND OUTPUT AND WITH DPD OF MODEL EXTRACTION USING BASEBAND INPUT AND PA OUTPUT WITHOUT DPD

ACLR	-2 BW Lower	-1 BW Lower	+1 BW Upper	+2 BW Upper
PA Output	54.064	35.33	35.682	53.582
DPD-PA w/BB Input	55.051	50.15	52.281	54.594
DPD-PA w/PA Input	55.799	51.23	54.315	55.411

plifier and PA when the VSA works without nonlinear distortion. ***Figure 5*** shows the normalized magnitudes of the time-domain waveform of the baseband waveform, PA input (or VSG RF output) and PA output after coarse synchronization (sample-level synchronization). Note that for this measurement, the VSG's RF power should be small enough to allow the PA to work on a linear area. If not, the DPD model extraction will fail.

In contrast to the PA DPD verification method, this method provides DPD for the full RF system and does not need to switch to capture PA input and output or turn the PA ON and OFF. The high-power amplifier can always be turned ON during DPD verification. Moreover, the pre-amplifier and the high-power amplifier are designed in an analog circuit board.

COMPARING DPD VERIFICATION METHODS

To compare the DPD performance associated with using the two DPD verification methods presented (that is with PA input or with baseband input), consider ***Figure 6***, which shows LTE DL 20-MHz DPD performances with a Mini-Circuit 1-W PA. The blue line is the spectrum of the PA output, while both the red and green lines are spectrums of the PA with DPD. The red line is spectrum with PA input and PA output extraction. The green line is spectrum with baseband input and PA output extraction. ***Table 1*** shows ACLR results of the PA output, DPD-PA with PA input and DPD-PA with baseband input.

From Figure 6 and Table 1, it is possible to see that the performance of the DPD-PA with PA input (red) is better than that of the DPD-PA with baseband input (green). The green spectrum is the DPD result with a full RF transmitter system. The DPD needs to remove the nonlinear distortion of the ADC and preamplifier, as well as the PA. The red spectrum is the DPD result with the measured PA.

CONCLUSION

Power amplifier linearization remains an important technique for current and emerging advanced communication systems. DPD verification can be accomplished using one of two methods. The more traditional approach uses an instantaneous complex baseband waveform and both PA input and output to extract a DPD model for a specific PA. A more novel approach extracts the DPD model by using a simulated baseband input and real PA output. This method eliminates the shortcomings of the more traditional method, allows designers to obtain high efficiency and avoid distortion caused by PA nonlinearities and also enables full RF linearization. ■

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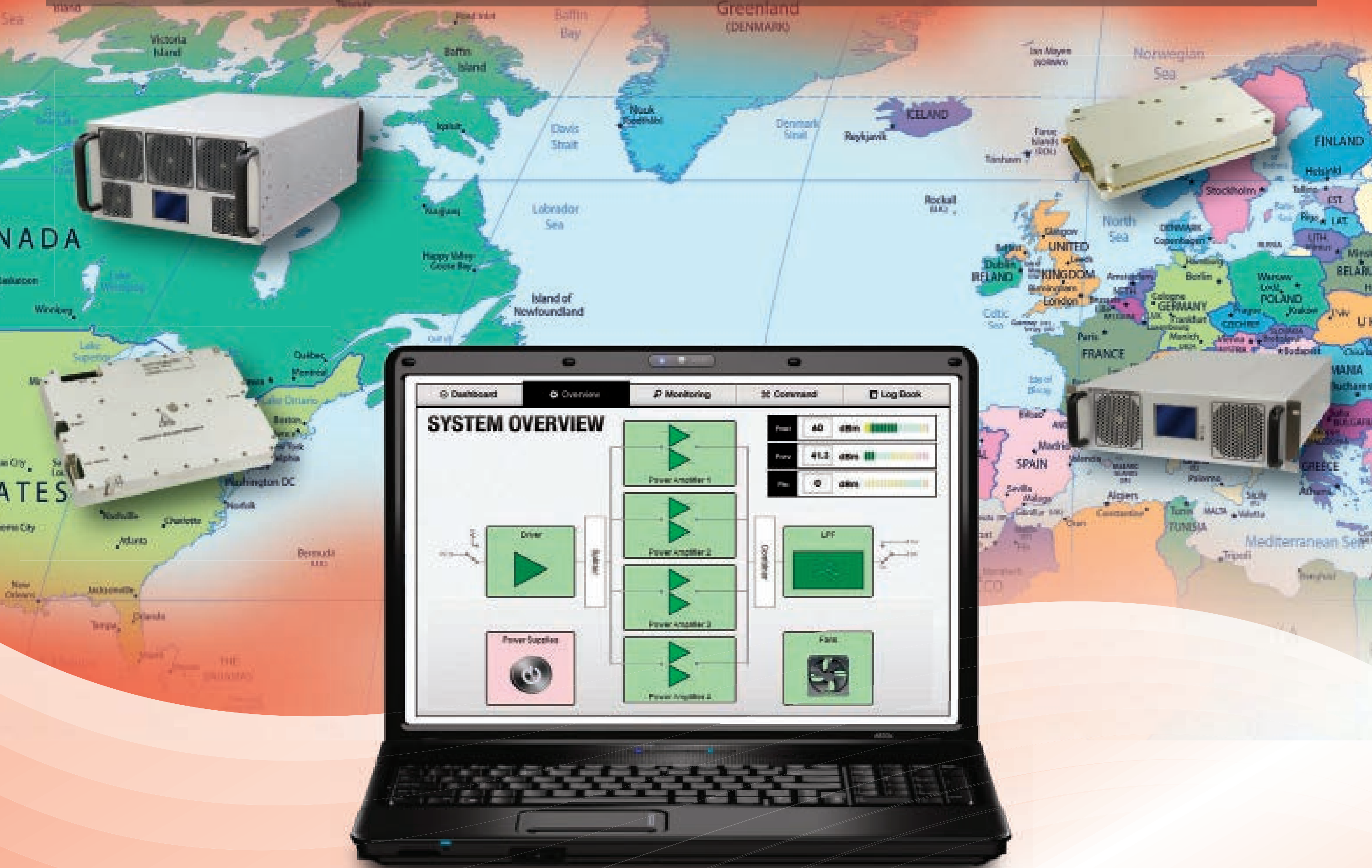

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A Miniaturized Impedance Transformer Employing PGS on GaAs

Using a meander line employing a periodic ground structure (PGS) on GaAs substrate, a highly miniaturized impedance transformer was developed for application to low impedance matching. Its size is 0.151 mm², which is 3.5 percent of the size of a conventional microstrip line impedance transformer on GaAs substrate. The meander line impedance transformer showed a good RF performance in the S/C band.

In wireless communication systems, low impedance transformation is required for impedance matching between active devices, because the input and output impedances of the active devices are much lower than 50 Ω in the microwave band.[1] Therefore, for an efficient impedance matching of microwave devices employed in wireless communication systems, an impedance transformer performing low impedance transformation between active devices is indispensable and should be highly miniaturized for integration in monolithic microwave integrated circuits (MMIC).

In this work, a highly miniaturized meander line impedance transformer, employing a periodic ground structure on GaAs substrate, was developed for application to low impedance matching components on MMICs.

A MEANDER LINE EMPLOYING PGS

In order to develop a highly miniaturized impedance transformer, a meander line employing PGS with a high capacitive element is used. ***Figure 1*** shows the structure of the meander line employing PGS. As shown, the PGS was inserted at the interface between a SiN film and the GaAs substrate and was electrically connected to the backside ground metal through the via-holes. As is well known, a conventional microstrip line without PGS has only a periodical capacitance C_a per unit length, but the meander line employing PGS has an additional capacitance C_b as well as C_a, due to PGS.

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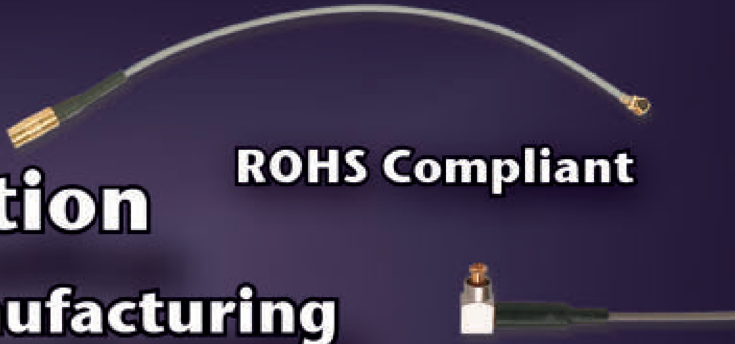

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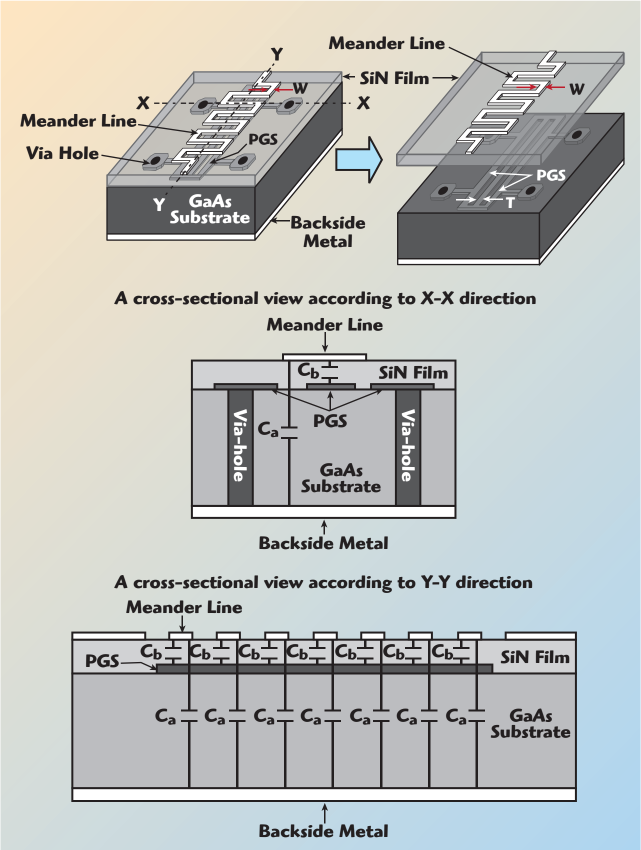

Fig. 1 Meander line employing a PGS.

C_b is an additional capacitance between the meander line and PGS, which is caused by the SiN film between meander line and PGS. Therefore, using the meander line with PGS, a short wavelength and low impedance transformer can be realized, due to an increase of capacitance, because Z_0 and λ_g are inversely proportional to the periodic capacitance. In other words, $Z_0 = \sqrt{L/C}$ and $\lambda_g = 1 / [\ f\times\sqrt{LC}]$.[2]

TABLE I

MEASURED CHARACTERISTIC IMPEDANCE (Z_0) AND WAVELENGTH (λ_g) OF THE MEANDER LINE EMPLOYING PGS AND A CONVENTIONAL MICROSTRIP LINE ON A GaAs SUBSTRATE

	Z_0	λ_g
Meander Line Employing PGS	10 Ω	1.72 mm
Microstrip Line Without PGS	80 Ω	20.3 mm

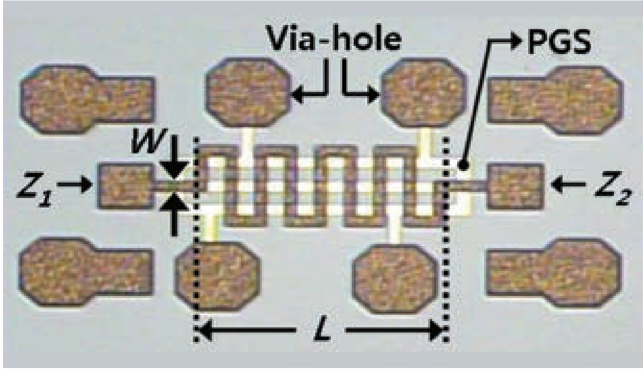

Fig. 2 Photograph of the meander line impedance transformer employing PGS on a GaAs substrate.

Table 1 shows the measured Z_0 and λ_g of a meander line employing PGS and a conventional microstrip line without PGS, which were fabricated on a GaAs substrate with a height of 100 µm. As shown in Table 1, the meander line employing PGS exhibits a much lower Z_0 and a shorter λ_g than the conventional microstrip line. The width of the PGS pattern (T) and line width (W) were set to 20 µm, and the line width of the conventional microstrip line is 20 µm. The wavelength was measured at 4.5 GHz. The results indicate that highly miniaturized and low impedance passive circuits can be realized by using the meander line employing PGS.

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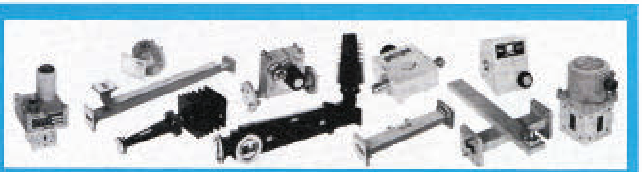

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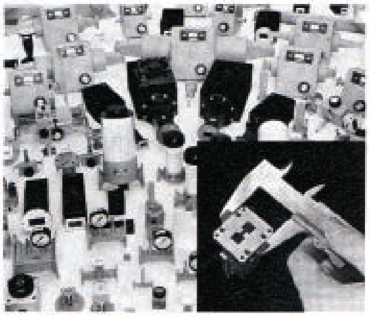

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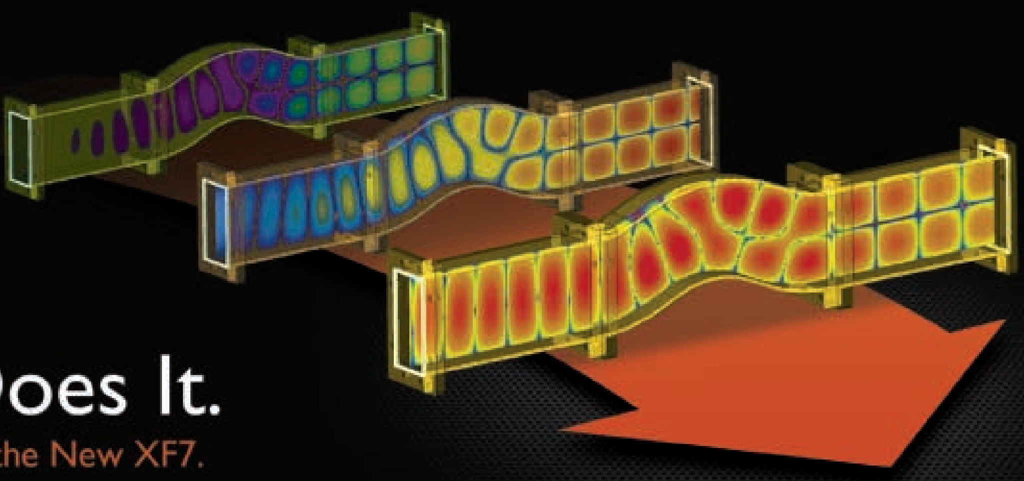

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ASL41S9	0.9	18	0.55	38	SOT89
ASL52T8	2.0	21	0.65	34	TDFN8

LNA w/o extra component

Part No.	Freq. (GHz)	Gain (dB)	NF (dB)	OIP3 (dBm)	Package
ANM1730	1.7~3.0	25	0.5~0.8	35	MCM3P

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AWB459	DC~3	19	24	41	SOT89
AWB589	DC~1	20	27	44	SOT89
AWB688	DC~1	21	30	44	SOIC8

GPS LNA

Part No.	Vd/Id (V/mA)	Gain (dB)	NF (dB)	OIP3 (dBm)	Package (mm)
ASL22N	3/8.5	29	1.1	16	UQFN6 (1x1)

CATV

Part No.	Vd/Id (V/mA)	Gain (dB)	Pout (dBuV)	CSO/CTB (dBc)	Package
ASL39D2	5/300	19	105	60/66	SOIC8
ASL59D4	6.5/390	20	108	60/63	TSSOP24
ASL882	12/520	22	110	60/66	TSSOP24

Optical Receiver

Part No.	Vd/Id (V/mA)	Photo.Pin (dBm)	Pout (dBuV)	CSO/CTB (dBc)	Package
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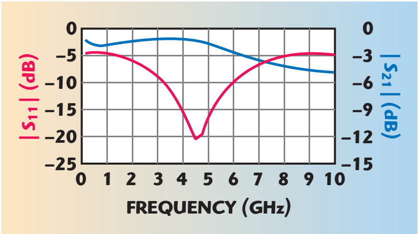
TABLE II

SIZE COMPARISON BETWEEN A MEANDER LINE IMPEDANCE TRANSFORMER USING PGS AND A CONVENTIONAL MICROSTRIP LINE IMPEDANCE TRANSFORMER ON A GaAs SUBSTRATE

	Line Width (mm)	*λ_g/4 Wavelength (mm)*	*Size (mm²)*
Conventional Microstrip Line Impedance Transformer (Without PGS)	0.85	5.07	4.31
Meander Line Impedance Transformer Employing PGS	0.351	0.43	0.151



▲ *Fig. 3 Measured return and insertion loss of the meander line transformer employing PGS.*

A MINIATURIZED MEANDER LINE IMPEDANCE TRANSFORMER EMPLOYING PGS ON GaAs MMIC

Figure 2 shows a photograph of the meander line impedance transformer employing PGS on a GaAs substrate. The characteristic impedance Z_0 of the impedance transformer is given by $Z_0 = \sqrt{(Z_1 \times Z_2)}$,[2] where Z_1 and Z_2 are the source and load impedance, respectively. In this work, Z_1 and Z_2 are 5 and 20 Ω, respectively. Therefore, the Z_0 of the meander line impedance transformer is 10 Ω. For an operating frequency of 4.5 GHz, the circuit length of the meander line impedance transformer employing PGS is 0.43 mm and the width of the impedance transformer including via holes is 0.351 mm. Therefore, the size of the meander line impedance transformer is 0.151 mm², which is 3.5 percent of the size of a conventional impedance transformer.[3] The size comparison of the impedance transformer is summarized in ***Table 2***. ***Figure 3*** shows the measured return loss S_{11} and insertion loss S_{21} of the meander line impedance transformer employing PGS on a GaAs MMIC. As shown, good RF performance can be observed from the meander line impedance transformer employing PGS. Concretely, the return and insertion losses are 20.7 and 1.5 dB, respectively, at the operating frequency of 4.5 GHz. From 3 to 5 GHz, the impedance transformer shows return loss values better than 9.5 dB and insertion loss values better than 2.5 dB.

CONCLUSION

A highly miniaturized meander line impedance transformer employing PGS on GaAs MMIC was developed for application to low impedance transformation. Its size was 0.151 mm², which was 3.5 percent of the size of the conventional microstrip line impedance transformer. According to the measured results, it was found that the impedance transformer showed good RF performances in S/C band. ■

ACKNOWLEDGMENT

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Conformal Antenna Array Design on a Missile Platform

Applications, ranging from communications to radar and even medical devices, depend on antenna arrays. Hand calculations successfully facilitate the construction of stand-alone arrays; however, what happens when the mounting platform becomes a part of the radiating system? Basic analytic techniques cannot easily account for obstructions created by aircraft engines, re-radiation from wings, irregular ground planes of cars or the curvature of a missile.

Antennas and antenna arrays targeted toward vehicular applications, often further complicate the design process with additional restrictions. Aircraft, in particular, require consideration of aerodynamic effects and the impact on radar scattering caused by the integration of external systems. As a result, designers tend to incorporate conformal antenna elements that cannot be realized through basic antenna theory.

These applications require 3D simulations to ensure that the final design meets all requirements, before physical prototyping or manufacturing can begin. This application note demonstrates the process of adding an electrically steerable, conformal antenna array to the body of a high speed missile. A specified surface area on a generic missile body and a set of design goals has been provided to illustrate the challenges of designing the array; however, this example does not represent any actual missile or antenna system in production.

PROJECT GOALS

The design goals of the conformal missile array include an operating frequency of 2.4 GHz, with a main beam gain greater than 10 dBi and sidelobe levels at least 20 dB down from the peak gain. The array must scan from broadside of the missile up to a 45° forward tilt toward the nose of the projectile. The missile is 2.3 m long and 24 cm in diameter. The array will be located on the cylindrical body of the vehicle, cannot interfere with the control surfaces and must fit within a 1 m by 10 cm footprint. For this application note, the commercial software package XF7 will be used to generate the simulated results.

ARRAY ELEMENT DESIGN

The first step of the process is to choose and design a single array element. The aerodynamics of the missile will be extremely sensitive to any perturbation to the surface, so a planar

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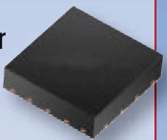

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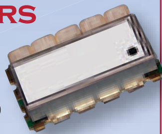

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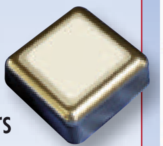

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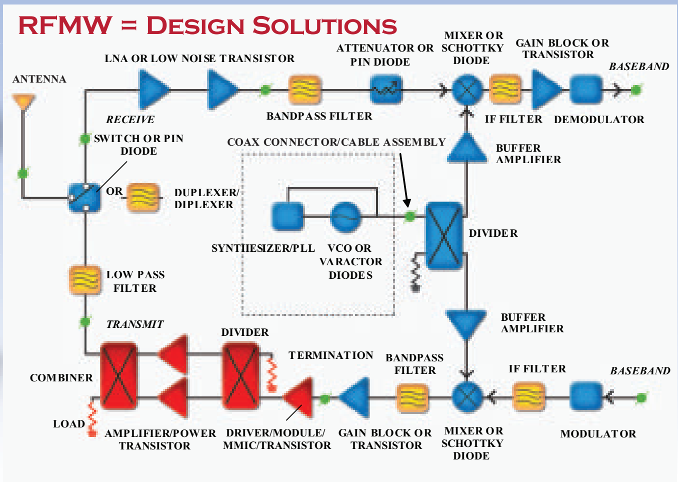

RF DIODES

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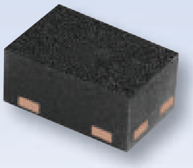
- Schottky
- Varactor
- Limiter
- Gunn



RF ATTENUATORS

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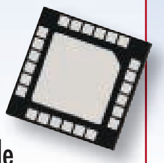

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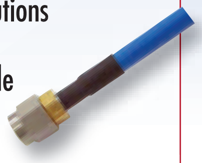

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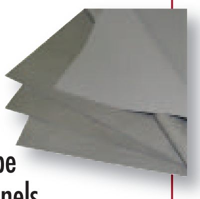

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TABLE I

PATCH PARAMETER EVOLUTION

Antenna	Feed Offset (mm)	Patch Diameter (mm)
Patch Antenna (Initial)	4.982	44
Patch Antenna (Final)	7.5	44.5
Bent Patch Antenna	7.5	45.25

conformal antenna is required. A circular patch antenna is chosen for this example. Several books, Balanis[1] for example, provide detailed design processes for the patch. Following the analytic design, a brief tuning process ensues. A parametric investigation of the feed location produces an antenna with an excellent return loss of 20 dB and a peak gain of 7.5 dBi at 2.4 GHz.

Having achieved acceptable performance with the flat patch, the next level of complication is introduced. XF7's CAD modeling tools bend the patch, substrate and ground plane to match the curvature of the missile body. XF7's conformal meshing tool allows the software to precisely capture the effects of this bend during simulation. The bend causes the operating frequency to shift slightly higher than desired to about 2.45 GHz; however, a quick parameter sweep finds an increased patch diameter that returns the operating frequency to the desired point. ***Table 1*** demonstrates the evolution of the patch parameters from the initial analytic design to the curved implementation.

ARRAY DESIGN

For the next step, a script from Remcom's XTend Script Library synthesizes an array design, based on the specified performance criteria. The script employs a Fourier transform technique to determine the appropriate amplitude and phasing of each array element and applies a modified Taylor distribution to the amplitudes to better control the sidelobes. As shown in ***Figure 1***, the inputs to the tool are the center frequency of 2.4 GHz, the horizontal beamwidth of 65°, the vertical beamwidth of 12° and the desired sidelobe suppression of 20 dB down from the peak. A maximum electrical downtilt of 45° is also entered. The script-based GUI recommends the minimum number of elements required in each dimension to meet the specifications and provides an estimated directivity of the proposed array.

The script suggests a 2 × 11 element array; however, the limited space on the missile body only accommodates a single column of antenna elements. The user opts for an initial design, using a 1 × 12 array of the circular patch elements and the script prepares the project using the calculated spacing, phases and amplitudes. The modified project uses parameterized spacing and amplitudes to expedite possible future parametric investigations or optimization. The element phasing

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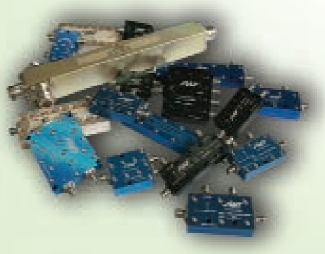

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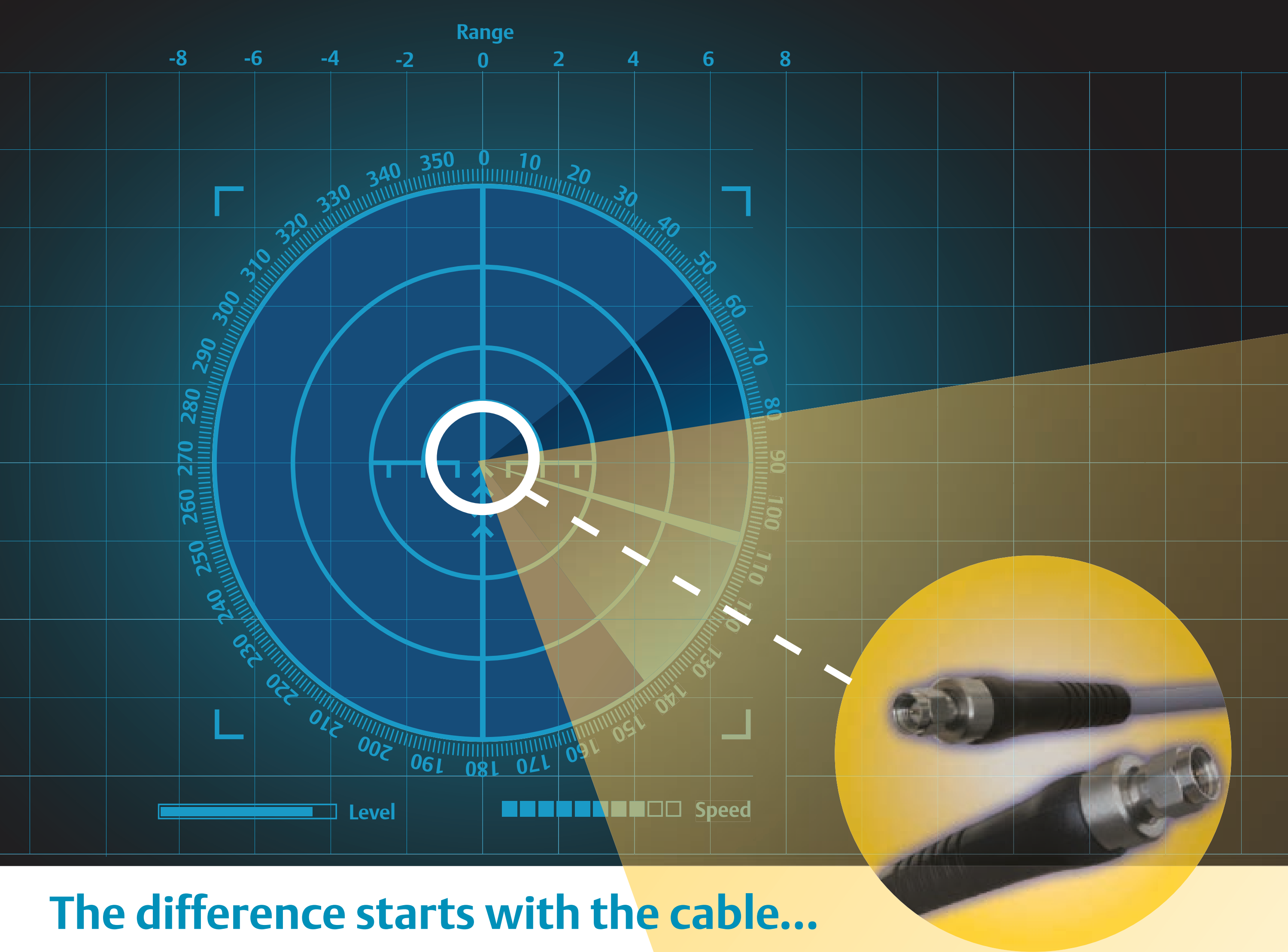

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is defined as a function of electrical downtilt to provide control over beam steering.

As with any simple analytic process, the Fourier transform technique includes certain assumptions. This approach assumes the radiation emanates from a uniformly illuminated aperture, which fails to account for the non-uniform field produced by the actual antenna elements. It also neglects fringe effects from the ground plane, substrate and edge of the antenna. As a result, it is expected that the initial array design may fail to meet some requirements and the initial flat design simulation results, shown in ***Figure 2***, indeed demonstrate a slightly high sidelobe level.

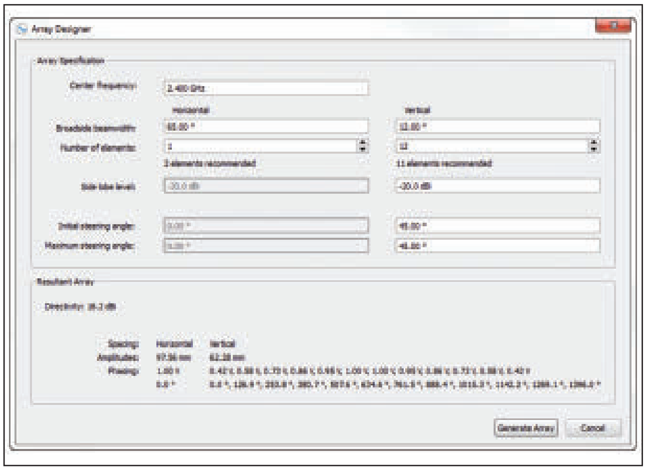

Fig. 1 Inputs to the array designer tool.

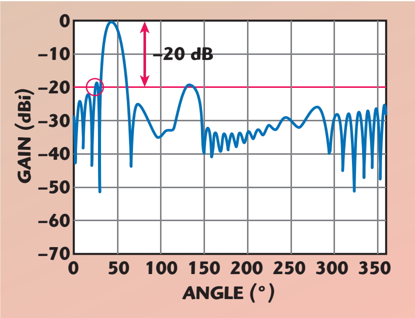

Fig. 2 Simulated antenna gain vs. angle.

XF7 provides multiple approaches to address this issue. A parameter sweep or optimization could be used to refine the array parameters in order to improve performance; however, a simpler option is to repeat the array design process with stricter criteria. The designer is run again with a tighter restriction of –34 dB sidelobe suppression. Following this process, the flat array greatly exceeds the target performance criteria as evidenced by comparing the blue and green plots shown in the revised radiation pattern of ***Figure 3***.

Having verified the array performance with the simple planar element, the user now applies the array definition to the previously tuned curved elements. The red plot in Figure 3 indicates that the curvature negligibly affects overall array performance, so no further tuning is required at this stage. The array is found to have a peak gain of nearly 14 dBi with sidelobe levels that exceed the original specifications.

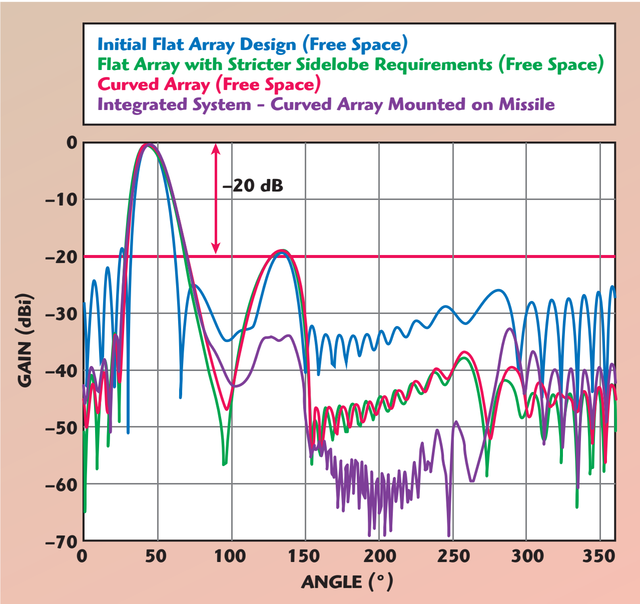

Fig. 3 Optimized simulated antenna gain vs. angle.

FINAL VALIDATION

The user integrates the curved array with the missile body in order to validate the overall design. As expected, the presence of the missile body does change the performance of the array and the final shape of the gain pattern; however, the resulting pattern still meets the design criteria. The final system exhibits greater than 14 dBi gain. Sidelobe suppression exceeds 32 dB as seen in the magenta plot of Figure 3. Altogether, the design requires no further adjustments. ***Figure 4*** displays multiple views of the completed system including a close-up view of the completed array on the missile body and two gain patterns. For these plots, the electrical downtilt parameter has been set for the full 45° forward tilt.

HARDWARE AND SIMULATION TIMES

The iterative nature of the design process often threatens to consume an unacceptable amount of time. This application note required numer-

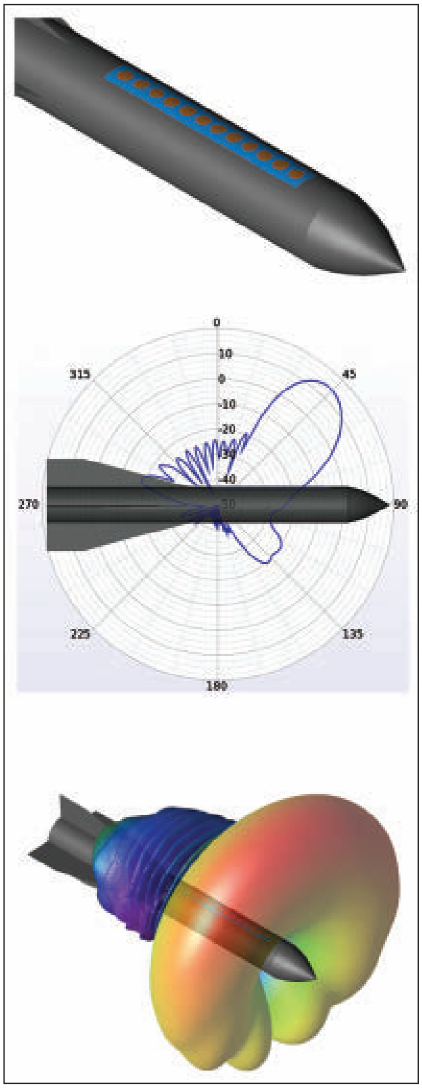

Fig. 4 Completed array on the missile body and two gain patterns.

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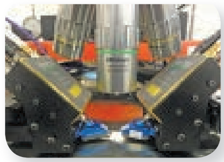

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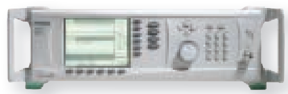

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TABLE II

SIMULATION TIME FOR DIFFERENT GPU

Hardware	Run Time (H:MM:SS)
Intel Core i7 CPU (2.8 GHz); 8 threads	3:13:00
Nvidia Tesla C2070 GPU; 1 GPU	0:29:40
Nvidia Tesla C2070 GPU; 2 GPUs	0:14:10
Nvidia Tesla C2070 GPU; 4 GPUs	0:08:50
Nvidia Tesla C2070 GPU; 6 GPUs	0:07:20

ous simulations to progress from the analytically designed patch through the initial array design to the final integrated system. In a real production environment, the number of simulations can easily increase by orders of magnitude. Antenna designs are often treated almost as an afterthought and antennas are expected to fit within ever decreasing volumes in order to make room for other system components. The evolution of the overall system generally translates to significantly modified requirements for the antenna subsystem.

The entire design and workflow of XF7 helps address the challenges of working within an iterative process; however, XF7's GPU acceleration offers the most easily measured time savings. It tremendously improves EM simulation performance by leveraging the power of CUDA capable GPUs from NVIDIA. For example, the fully-integrated system in this example requires approximately 1.5 GB of RAM for simulation. An eight core Intel core i7 CPU needs over three hours to complete this work. However, the same simulation can be completed in just over seven minutes, using multiple GPUs. See ***Table 2*** for more detailed timing information.

CONCLUSION

This application note focused on the design of a conformal array on the surface of a missile. The initial circular patch design chosen provided a good start for developing the curved array, due to the minimal impact that bending had on the return loss and gain of the antenna. The array synthesis tool rapidly provided a good design, with only slight adjustment needed to reach the required sidelobe levels. The final design was easily integrated into the full missile platform and simulated with good results, completing the final step in the process. It was also shown that a complex 3D simulation including multiple array elements with curved surfaces that could take several hours was completed within a few minutes. Applying these techniques together can help increase productivity, while increasing the fidelity of the design, all before physical prototyping has begun. ■

Reference

1. C.A. Balanis, *Antenna Theory*, 3rd edition, John Wiley & Sons Inc., Hoboken, NJ, 2005.

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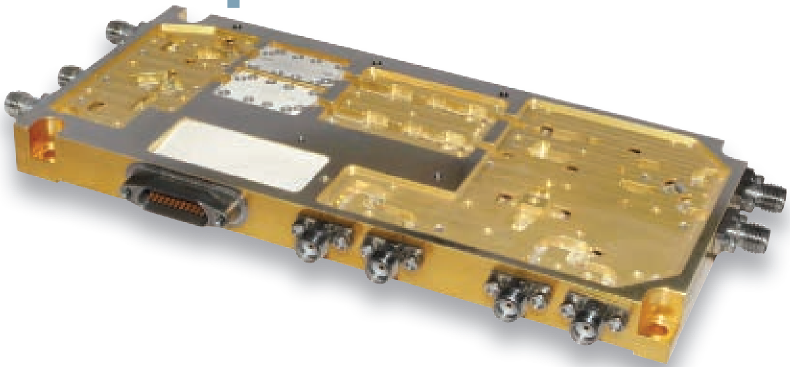

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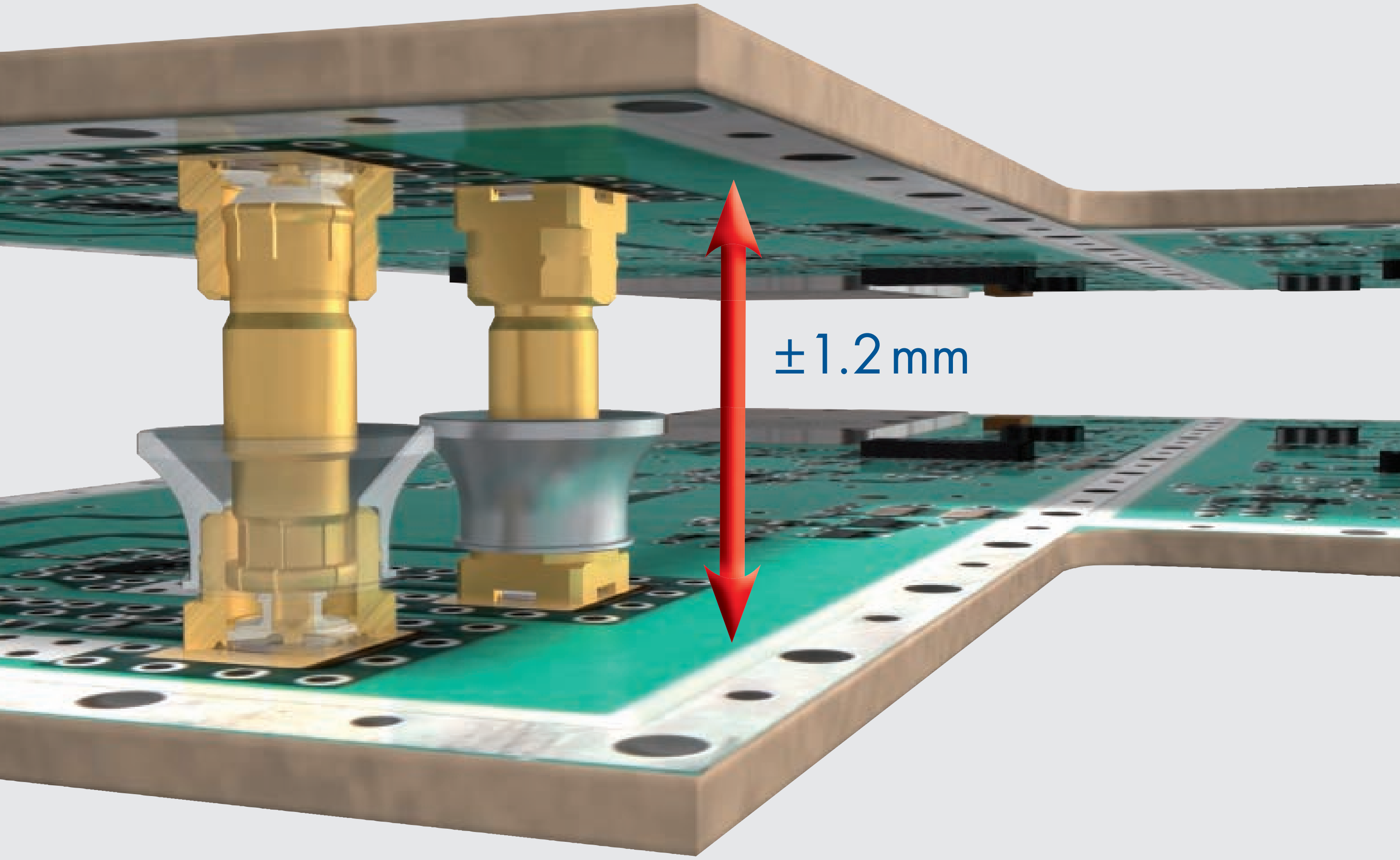

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Characteristic modes describe the current distributions and radiation characteristics of an object like an antenna, in a similar way that waveguide modes describe which propagating modes are supported for a particular guiding geometry. FEKO Suite 6.2 characteristic mode analysis (CMA) thus provides antenna designers with information on what type of radiation can be supported by an arbitrary geometry. This information extends to representations of the current distribution for each radiating mode, as well as near field and far field radiation that this mode contributes to the total performance of the antenna (see ***Figure 1***). Antenna designers are thus empowered to design new antennas based on in-depth knowledge of the structure's radiating properties, rather than on educated guessing or brute force optimization-based design methods.

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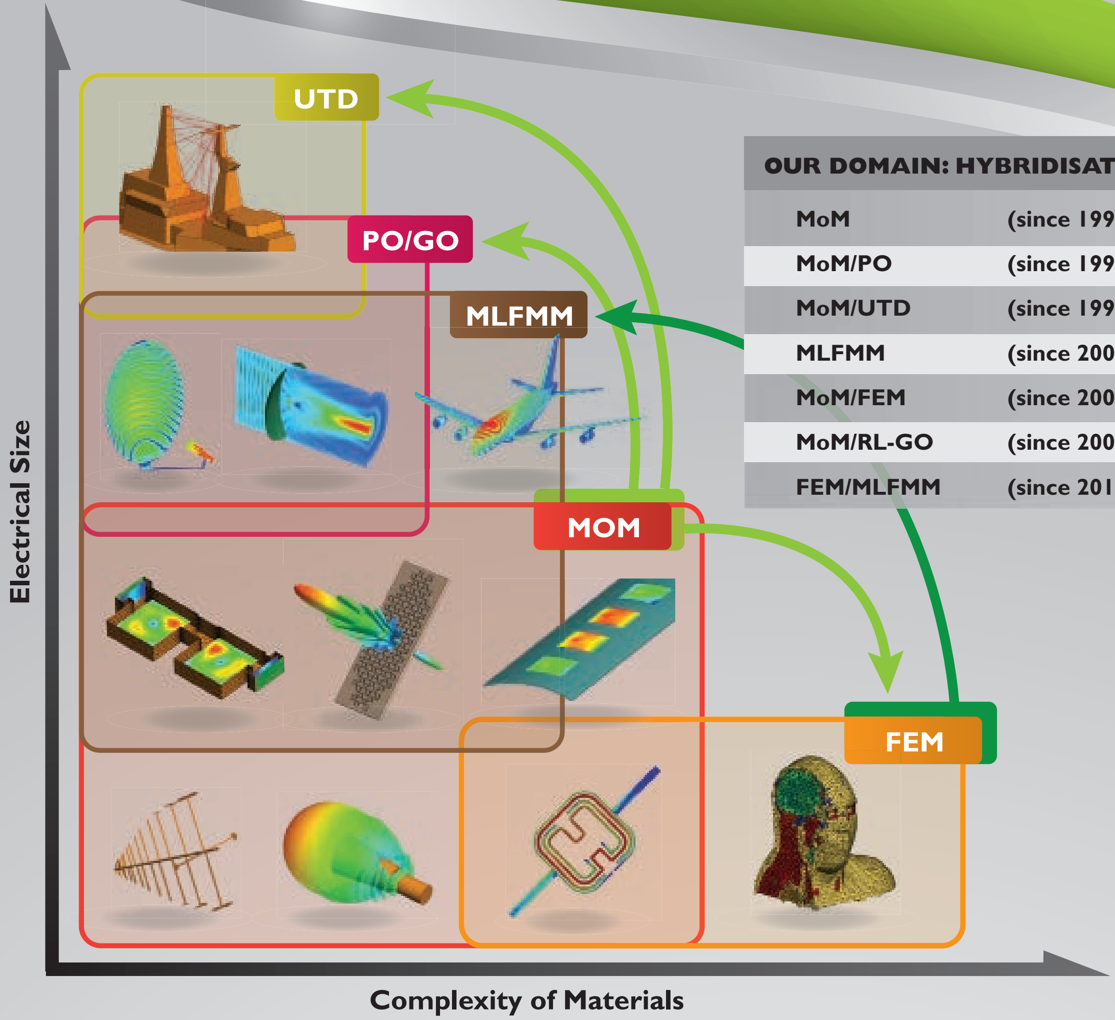

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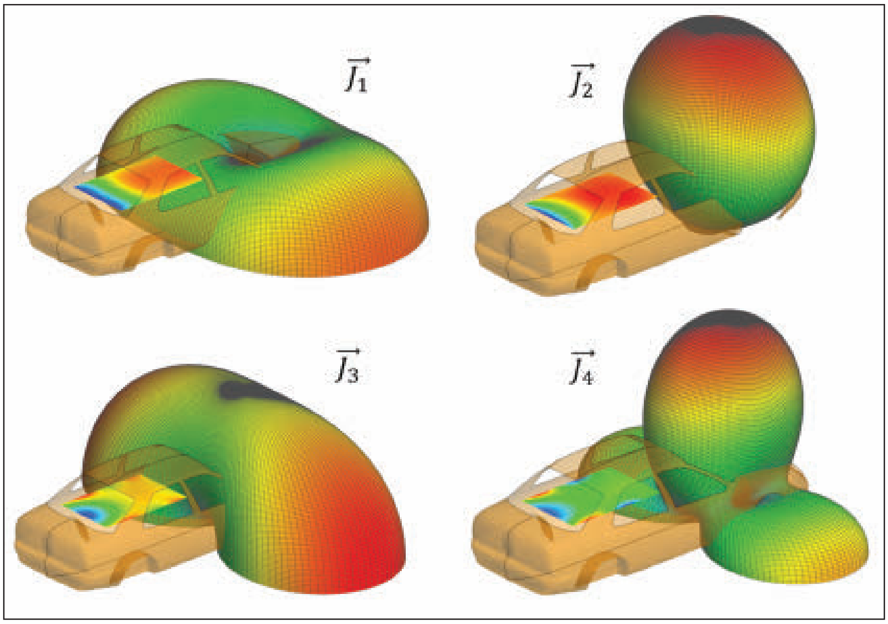
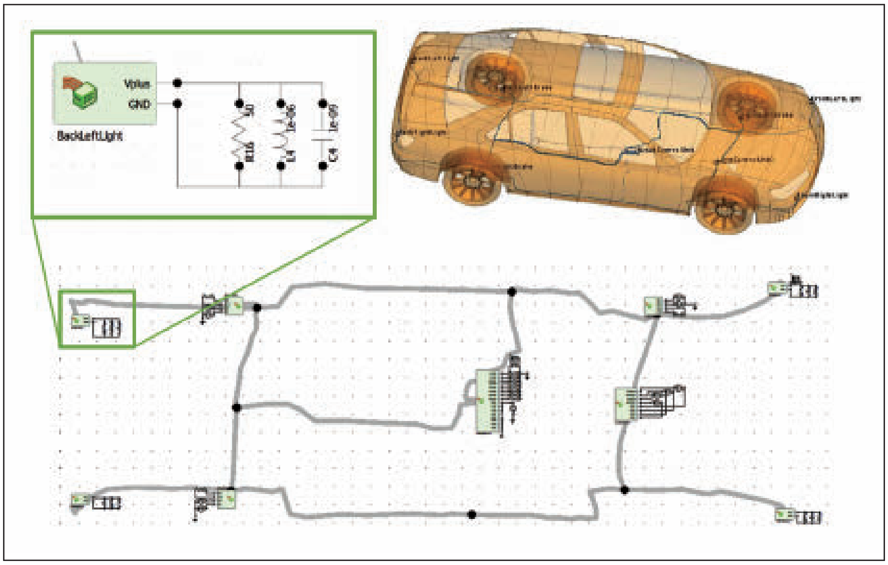


▲ *Fig. 1 Characteristic modes one to four for a vehicle.*



▲ *Fig. 2 Schematic layout of cables in a vehicle in CADFEKO.*

FAST ARRAY SOLVER

The Domain Green's Function Method (DGFM) forms the mathematical basis of the new solver for large, finite sized arrays that was introduced in FEKO Suite 6.2. The fast array solver provides an optimal way of modeling very large finite arrays, with computational complexity (memory and run-time) that scales relative to the size of a single element of the array, rather than relative to the size of the entire array. A powerful feature of the solver is that it does not require any particular structure or pattern in the placement of array elements and all array elements can be placed arbitrarily. CADFEKO also presents tools that enable the simple setup of such large arrays, including placement of elements and feeding of each element.

HIGHER ORDER BASIS FUNCTIONS

The heart of FEKO is still integral based formulations to Maxwell's equations, in the form of the Method of Moments (MoM) and Multilevel Fast Multipole Method (MLFMM). The MoM formulation was strengthened in FEKO Suite 6.2 with the introduction of higher order basis functions (HOBF). HOBF bring a wealth of possible uses, which is much coarser surface meshing for solutions of equal accuracy to the finer meshed solutions of previous versions of FEKO. Alternatively, solution accuracy may be improved without remeshing a coarse mesh by simply increasing the order of the solution.

CABLES IN AN EM ENVIRONMENT

Modern antenna designers cannot merely design antennas in isolation – they have to be aware of the impact that their antennas will have on the environments where they will operate and vice versa. One such aspect that FEKO is well suited to investigate is the interaction between antennas or unwanted radiating devices and cables. This can be either where radiation couples into cables (a cable irradiation problem), or where cables radiate energy that couple into external structures (a cable radiation problem) or, of course, the combination of the two. FEKO's technology supports the investigation of such problems via a wide range of technologies, including a unique implementation of a formulation that combines the MoM with Multiconductor Transmission Line (MoM/MTL) theory. The CADFEKO interface also supports the setup of various cable types and combinations of these to form cable bundles that may be distributed in various environments. In addition to the existing cable types (such as ribbon, coaxial, etc.) the FEKO Suite 6.2 solver now also supports twisted pair cables and the GUI helps users bundle cables with an "auto-bundle" feature and a new schematic view to connect cables in complex configurations (see ***Figure 2***).

FEKO Suite 6.2 introduces new features to the product's existing suite of solutions and also builds on existing methods to improve them even further. The product has a wide range of applications and will continue to improve on solver methods and the range of applicability of the product in the future.

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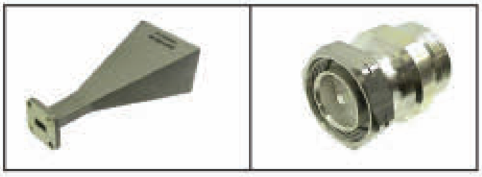

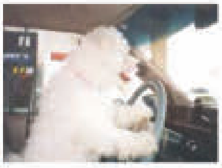

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Affordable Mixed Domain Debug and Analysis

Last year, Tektronix launched a new category of oscilloscope with the introduction of the MDO4000 Series, the first, and currently the only, oscilloscope on the market with a built-in spectrum analyzer. Now the company is introducing two new entry level models that put breakthrough time and frequency domain analysis in the hands of engineers at more affordable price levels.

Inexpensive or "cheap" RF technologies are being integrated into everyday applications from apparel tags, to livestock monitoring clips, price displays on store shelves and short-range wireless remote control of household objects. While many of these are lower-performance applications, the addition of RF makes debug challenges greater than ever. The new MDO4000 models address this trend by providing a lower cost entry point solution that allows engineers to capture time-correlated analog, digital and RF signals for a complete system view, saving days or even weeks of debug time.

Like other MDO4000 models, the new MDO4014-3 and MDO4034-3 models offer four analog channels, 16 digital channels and one RF channel. To achieve prices starting at $12,200, the new models offer lower analog bandwidth of 100 and 350 MHz respectively, sufficient for many inexpensive RF applications. RF frequency range for all models extends from 50 kHz to 3 GHz.

The MDO4000 packs a wide array of functionality into a compact form factor that helps to conserve limited bench space. Just 5.8" deep, it combines the functionality of an oscilloscope, logic analyzer, spectrum analyzer and protocol analyzer at the price of an entry level spectrum analyzer.

"CHEAP" RF APPLICATIONS GROWING

In today's world, it seems like wireless is showing up almost everywhere, an observation supported by industry watchers. For instance, iSuppli estimates that 1 billion wireless LAN devices will ship in 2012 with 2 billion expected by 2014. Similarly, ABI Research says that wireless sensor networks will grow from 10.2 million chipsets in 2009 to 645 million in 2015, a 99.6 percent annual growth rate. In the RFID

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Model Number	Frequency (MHz)	Pout (Watts)
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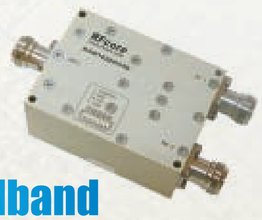

Broadband High Power Switches

Model Number	Frequency (MHz)	Pout (Watts)
RSW002050H50F	20-500	100
RSW0525H50F	500-2500	100
RSW1030H52C	1000-3000	160
RSW1020H54D	1000-2000	200
RSW2030H54D	2000-3000	200

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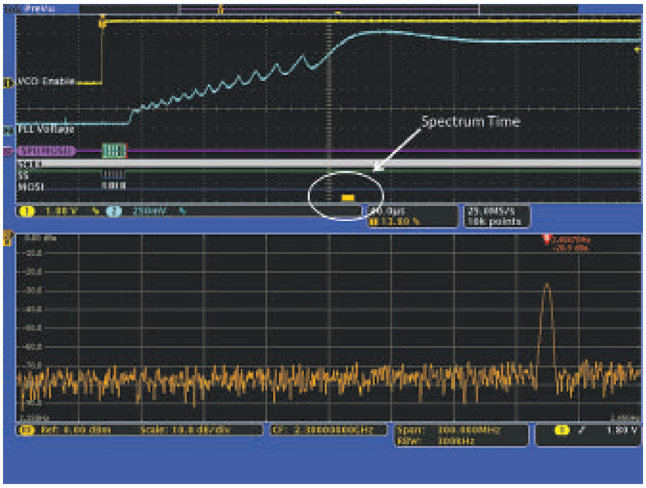
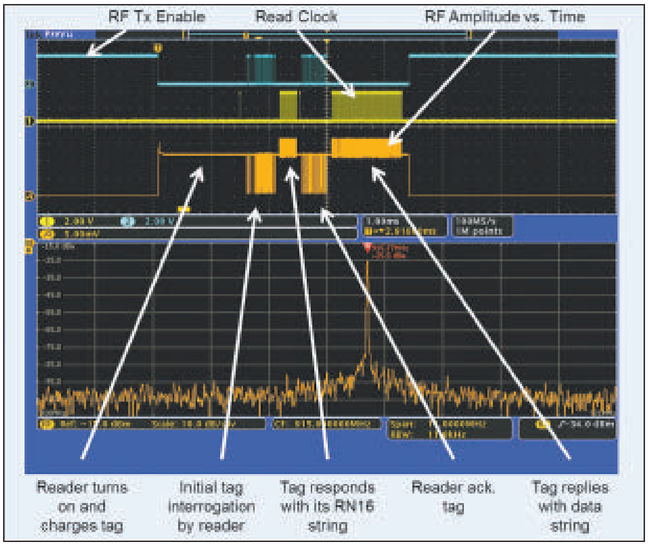
segment, forecasts call for shipments of 3.98 billion tags in 2012, up more than 1 billion over 2011 shipments.

Engineers tasked with integrating RF face a number of design challenges, including the need to not only characterize, debug and test the RF interface, but also to ensure that the RF systems interact nicely with the rest of the electronics in the device. Interference and interaction from RF sources in the environment, as well as other electrical signals in the system, also need to be characterized and understood in order to successfully integrate RF technology into a product.



▲ *Fig. 1 The MDO4000 displays time correlated view of both the time and frequency domain.*



▲ *Fig. 2 The MDO4000 makes RFID system analysis fast and efficient.*

Based on the Tektronix MSO4000B mixed signal oscilloscope series, the MDO4000 Series offers intuitive operation and information-rich displays. When both the RF channel and any analog or digital channels are on, the oscilloscope display is split into two views, as shown in ***Figure 1***. The upper half of the display is a traditional oscilloscope view of the time domain. The lower half of the display is a frequency domain view of the RF input. These two views are tied together by a feature called Spectrum Time, which is indicated by the small orange bar at the bottom of the time domain view. Spectrum Time indicates where in time the spectrum shown in the lower half of the display came from. Spectrum Time can be moved anywhere in the acquisition, enabling the user to see time correlated analog, digital and RF signals.

In addition, the time domain window can also provide support for RF time domain traces which show the user instantaneous amplitude, frequency or phase over time as shown in ***Figure 2***.

INTEGRATING RFID

Given its rapid growth, RFID is likely to be a segment that many engineers will need to address in the next few years. However, integration of RFID into a system raises a number of questions that require multi-domain analysis. Does the RF signal from the reader interfere with proper operation of other parts of the system? Do the system clocks, or switching power supplies, or high-speed data interfaces, affect the performance of the RFID system? Are the RF signals being properly gated, controlled and demodulated in sync with the command and control signals from the rest of the system?

MINIATURE FOOTPRINT

ULTRA WIDE BANDWIDTH VCO

0.3" x 0.3" x 0.08"

Model	Frequency Range (MHz)	Tuning Voltage (VDC)	DC Bias VDC @ I [Typ.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]	Size (Inch)
DCO Series					
DCO50100-5	500 - 1000	0.5 - 15	+5 @ 34 mA	-100	0.3 x 0.3 x 0.08
DCO6080-3	600 - 800	0 - 3	+3 @ 15 mA	-105	0.3 x 0.3 x 0.08
DCO7075-3	700 - 750	0.5 - 3	+3 @ 12 mA	-108	0.3 x 0.3 x 0.08
DCO80100-5	800 - 1000	0.5 - 8	+5 @ 26 mA	-111	0.3 x 0.3 x 0.08
DCO8190-5	810 - 900	0.5 - 16	+5 @ 34 mA	-118	0.3 x 0.3 x 0.08
DCO100200-5	1000 - 2000	0.5 - 24	+5 @ 36 mA	-95	0.3 x 0.3 x 0.08
DCO1198-8	1195 - 1205	0.5 - 8	+8 @ 30 mA	-115	0.3 x 0.3 x 0.08
DCO170340-5	1700 - 3400	0.5 - 24	+5 @ 29 mA	-90	0.3 x 0.3 x 0.08
DCO200400-5 DCO200400-3	2000 - 4000	0.5 - 18	+5 @ 46 mA +3 @ 46 mA	-90 -89	0.3 x 0.3 x 0.08
DCO300600-5 DCO300600-3	3000 - 6000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-80 -78	0.3 x 0.3 x 0.08
DCO400800-5 DCO400800-3	4000 - 8000	0.5 - 18	+5 @ 20 mA +3 @ 20 mA	-78 -76	0.3 x 0.3 x 0.08
DCO432493-5 DCO432493-3	4325 - 4950	0.5 - 11	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.08
DCO450900-5 DCO450900-3	4500 - 9000	0.5 - 18	+5 @ 20 mA +3 @ 20 mA	-76 -74	0.3 x 0.3 x 0.08
DCO473542-5 DCO473542-3	4730 - 5420	0.5 - 22	+5 @ 20 mA +3 @ 20 mA	-88 -86	0.3 x 0.3 x 0.08
DCO490517-5 DCO490517-3	4900 - 5175	0.5 - 5	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.08
DCO495550-5 DCO495550-3	4950 - 5500	0.5 - 12	+5 @ 22 mA +3 @ 22 mA	-83 -85	0.3 x 0.3 x 0.08
DCO5001000-5 DCO5001000-3	5000 - 10000	0.5 - 18	+5 @ 20 mA +3 @ 20 mA	-75 -73	0.3 x 0.3 x 0.08
DCO579582-5	5780 - 5880	0.5 - 10	+5 @ 20 mA	-90	0.3 x 0.3 x 0.08
DCO608634-5 DCO608634-3	6080 - 6340	0.5 - 5	+5 @ 20 mA +3 @ 26 mA	-85 -86	0.3 x 0.3 x 0.08
DCO615712-5 DCO615712-3	6150 - 7120	0.5 - 18	+5 @ 22 mA +3 @ 22 mA	-85 -83	0.3 x 0.3 x 0.08

Model	Frequency Range (GHz)	Tuning Voltage (VDC)	DC Bias VDC @ I [Typ.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]	Size (Inch)
DXO Series					
DXO810900-5 DXO810900-3	8.1 - 8.925	0.5 - 15	+5 @ 32 mA +3 @ 32 mA	-82 -80	0.3 x 0.3 x 0.08
DXO900965-5 DXO900965-3	9.0 - 9.65	0.5 - 12	+5 @ 27 mA +3 @ 27 mA	-80 -78	0.3 x 0.3 x 0.08
DXO10701095-5	10.70 - 10.95	0.5 - 15	+5 @ 25 mA	-82	0.3 x 0.3 x 0.08
DXO11441200-5	11.44 - 12.0	0.5 - 15	+5 @ 30 mA	-82	0.3 x 0.3 x 0.08
DXO11751220-5	11.75 - 12.2	0.5 - 15	+5 @ 30 mA	-80	0.3 x 0.3 x 0.08
DXO14851515-5	14.85 - 15.15	0.5 - 15	+5 @ 30 mA	-74	0.3 x 0.3 x 0.08

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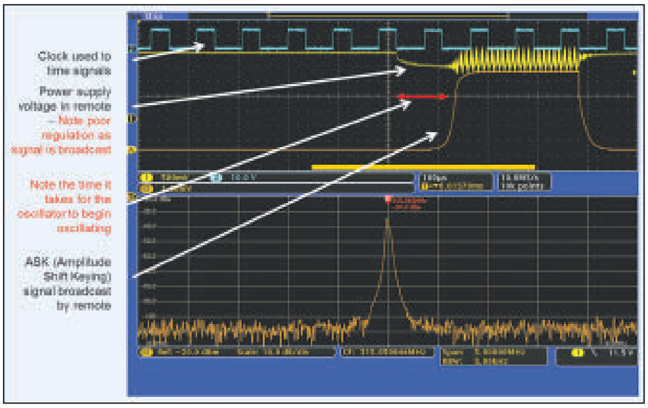
As shown in the RFID application example in Figure 2, the MDO4000 correlates RF activity with the rest of the system under test for easy device debug and verification. In a single acquisition, it is able to capture the RF communications from both the reader and the tag while allowing the designer to visualize other critical system signals.



▲ *Fig. 3 The MDO4000 provides a triggered acquisition system that is fully integrated with the RF, analog and digital channels.*

COORDINATED TRIGGER SYSTEM CAPTURES ANALOG, DIGITAL AND RF

In ***Figure 3***, the MDO4000 is used to see time correlated events across a wireless power switch. In this case, a single trigger event coordinates an acquisition across all channels, allowing the user to capture a spectrum at the precise point in time where an interesting time domain event is occurring. A comprehensive set of time domain triggers are available, including Edge, Sequence, Pulse Width, Timeout, Runt, Logic, Setup/Hold Violation, Rise/Fall Time, Video and a variety of parallel and serial bus packet triggers.

FEATURES

The MDO4000 Series addresses the needs of the more than 60 percent of engineers facing the need to debug systems in both the time and frequency domains. It incorporates a notable number of features including the following (many of which are reported to be industry firsts):

- Mixed domain oscilloscope with the functionality of an oscilloscope and spectrum analyzer in a single instrument.
- Capability to capture time-correlated analog, digital and RF signals for complete system visibility.
- RF Spectrum Time that makes it possible to see how the spectrum changes over time or with device state.
- Support for up to 3 GHz of capture bandwidth in a single acquisition. By comparison, most modern spectrum analyzers have just 10 MHz capture bandwidth.
- RF Time Domain traces to show how the amplitude, frequency or phase of the RF input signal changes relative to time.
- RF Trigger Qualification offers industry triggers on RF signals to further isolate the RF event of interest.

NEW PRE-AMPLIFIER, SIGNALVU-PC

In addition to the new MDO4000 models, Tektronix also announced the TPA-N-PRE pre-amplifier for use on all MDO4000 oscilloscopes. This new pre-amplifier further lowers the already low noise floor of the RF channel, enabling engineers to pull very low level signals out of the noise.

Also adding to the versatility of the MDO4000 is the availability of SignalVu-PC software that provides deep, offline analysis of complex signals. SignalVu-PC simplifies validation of wideband designs and characterization of wideband spectral events and speeds up time-to-insight by showing the time-variant behavior of wideband signals.

SignalVu-PC offers extensive vector signal analysis functionality spanning spectrum, spectrogram and RF measurements, including analog modulation analysis, adjacent channel power, CCDF, occupied bandwidth plus amplitude, frequency and phase vs. time. Options for more advanced analysis functions are also available including modulation, pulse, settling time, audio and flexible OFDM measurements. Acquisitions from all current Tektronix performance and value real-time oscilloscopes, including the spectrum analyzer in the MDO4000, can be analyzed with SignalVu-PC, adding deep analysis capabilities to these broadband acquisition systems.

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Carrier Grade, FDD Radio Using E-Band

Paolo Galbiati, PLM Director of SIAE MICROELETTRONICA, outlines how the company developed from humble beginnings in Milan in the 1950s to become a global player in the 21st century. Find this interview online at www.mwjournal.com/Galbiati.

Executive Interviews

The ALFOplus Series is a full outdoor, full IP, fully featured next generation microwave radio. It is a zero footprint solution, fully integrable with 3G, 4G and LTE nodes, making the series ideal for fast and flexible evolution toward full IP networks with high radio capacity and performance. With its advanced Ethernet features and complete synchronization management (SyncE and 1588v2), ALFOplus is a state-of-the-art IP radio, providing the foundation for leading edge networks.

The latest in the ALFOplus Series is the ALFOplus80, which is a carrier grade, FDD radio for E-Band applications. This next generation solution is an alternative to expensive fiber deployment, while retaining the same capacities and performance.

ALFOplus80 is state-of-the-art, not only from a technological point of view but also from an engineering perspective, being totally produced using pick and place and SiP technologies, even at such high frequencies when E-Band solutions are generally based on discrete/mounted components.

The radio provides up to 2.5 Gbps radio net throughput with down to 5 μs latency, representing an ideal solution for LTE (even in CPRI architecture) and for high capacity networks deployment, either as an alternative or in conjunction with fiber. With 64 QAM and ACM + Adaptive Symbol Rate (ASR) from 4 QAM up to 64 QAM, ALFOplus80 achieves high reliability for in-field applications.

ULTRA HIGH CAPACITY

With 2.5 Gbps net throughput and its zero-footprint characteristic, ALFOplus80 is suitable for ultra high capacity wireless links in urban environments for all carrier-class applications (mobile backhaul, enterprise, ISP). Latest synchronization techniques and advanced Ethernet/IP functionalities make it a state-of-the-art IP radio.

ALFOplus80 supports the latest SIAE MICROELETTRONICA modem techniques, including the Hitless ACM engine from 4 to 64 QAM and the company's advanced Multi-layer Header Compression algorithm. Split mount

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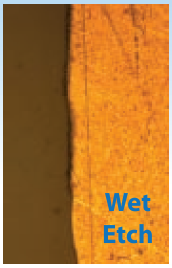

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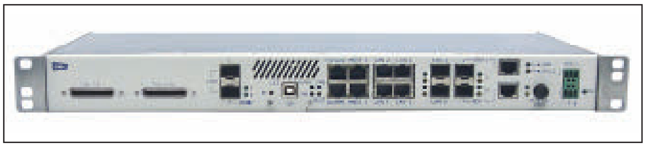

▲ *Fig. 1 Split mount architecture is also available by connecting ALFOplus80 with the AGS-H indoor unit, shown here.*

architecture is also available connecting ALFOplus80 with the AGS-H indoor unit (AGS-Hybrid), which is shown in ***Figure 1***.

This architecture provides additional High Capacity Native TDM traffic transport up to 2xSTM-1 + 16xE1, which are transported through this single NE System. Moreover, additional interfaces (4xGE) and all reliability schemes (1+1 HSB, G.8032 Ring Protection) specific to traditional split mount systems are also available.

Interconnection between ALFOplus80 and AGS-H can be chosen to be either electrical or optical; in the case of electrical connectivity ALFOplus80 can be powered by AGS-H or by a switch/router with Power over Ethernet (PoE) directly through LAN data cable.

Other key features include 71 to 76 GHz/81 to 86 GHz frequency ranges and 250 MHz, 500 MHz, 750 MHz and 1.000 MHz channel bandwidths, a Packet Header Compressor, supporting multi-protocol and Enhanced Tunneling protocol stacks, together with Linux or Unix based NMS, HTML based local access (no Flash needed).

'FIBER LIKE'

In addition, ALFOplus80 can be configured as fixed throughput equipment, in order to provide 'fiber-like behavior' with down to 5 μs latency. The ALFOplus80 is therefore ideal for high capacity and reactive network deployment. Being 'fiber like' in terms of performance and capacity, and demonstrating installation agility and deployment cost saving, it is suitable for next generation 4G/LTE architecture.

It is also a good choice for dedicated 'high value' and strategic connections such as: An alternative to or to complement multiGigabit high capacity fiber deployment; fiber backup and disaster recovery; CPRI transport for the distributed deployment of small cells; mobile and 4G/LTE network backhaul; micro and macro cellular network infrastructure; high capacity multiGigabit leased lines; carrier grade connection to service providers (ISP); municipal and private network backbones; Gigabit LAN/WAN backbone connection; and high capacity TDM transport (PDH+SDH) in E-Band (with AGS-H).

LTE architecture requires the radio link to have total flexibility of installation in different and changing network topologies and complete traffic management for providing a complete multi-services solution. With the forerunning ALS and ALFOplus Series, complemented by the ALFOplus80 Series, SIAE MICROELETTRONICA offers a complete set of solutions to address these requirements with carrier grade performance.

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The Aethercomm model number SSPA 2.9-3.1-300 is a high power, pulsed or CW GaN RF amplifier that can be employed in radar or other applications throughout the S-Band frequency range. This amplifier is optimized for operation from 2.9 to 3.1 GHz. The devices in the amplifier are not matched and therefore can operate from 2.7 to 2.9 GHz or 2.7 to 3.5 GHz with similar performance.

This power amplifier is ideal for radar platforms as it is robust and offers high power and excellent power added efficiency while maintaining compliant pulse fidelity. It operates with a base plate temperature of –40° to +85°C. It is packaged in a modular housing that is approximately 5.00" (width) by 8.00" (long) by 1.94" (height). The weight of this unit is 2.5 pounds typical. This amplifier has a typical peak output power of 300 to 400 watts at room temperature. Noise figure at room temperature is 10 dB typical, and the power flatness across the band is typically ±0.25 dB. Input and output VSWR is 2.0:1 typical.

This PA operates from a +50 V DC input voltage. The SSPA includes an external DC blanking command that enables and disables the module in 5.0 µsec typical. A logic low or open circuit disables the amplifier and logic high will enable the amplifier. Standard features include over/under voltage protection and reverse polarity protection. The output port is fully protected from an open or short circuit presented to this port with no damage. Input/output RF connectors are SMA female. DC and command voltages are accessible via a DSUB connector.

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Compact 0.9 to 40 GHz USB Controlled Tuner

diminuSys has expanded its line of wideband USB controlled tuners with the DWT-P940 for continuous 0.9 to 40 GHz coverage. The DWT-P940 offers wide instantaneous bandwidth and dynamic range, along with portability, affordability and ease of operation. With seamless high-speed tuning over the 0.9 to 40 GHz band, the DWT-P940 offers simultaneous non-inverting IF outputs at 900, 120 and 21.4 MHz with instantaneous bandwidth of 200 MHz (the 500 MHz option drives a 750 to 1250 MHz IF output).

The DWT-P940 employs sub-octave preselection with the ability to bypass all input filtering. Overall gain is adjustable from –40 to +20 dB and tracks between the three IF outputs. Broadband noise methods are employed for preservation of level measurement accuracy. Control of the tuner is via USB 2.0 or 3.0 with included applications for Windows and Linux. A simple native command set allows execution and proprietary application development for desktop and smartphone platforms.

The DWT-P940 is an ideal pre-tuning solution for those in need of extended frequency coverage for vintage EMI, TEMPEST or surveillance receivers with upper limits of 1 or 2 GHz. As the perfect alternative to budgeting for an unfamiliar path to 40 GHz, the DWT-P940 performs microwave tuning and preselection for established systems with only minimal impacts on level measurement accuracy, sensitivity and intermodulation. Available options include 500 MHz instantaneous bandwidth, low phase noise, enhanced tuning speed and increased internal reference stability.

The DWT-P940 employs a field replaceable 2.92mm input connector, and BNC or SMA outputs for the three IFs, reference in and reference out. The unit operates on 12 VDC and includes a 120/240 VAC universal power supply.

diminuSys, Irvine, CA
(800) 809-4230, (949) 207-3923,
info@diminusys.com,
www.diminusys.com.

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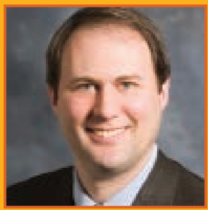
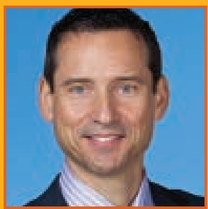
KEYNOTE SPEAKERS



Bill Swift
Vice President of Engineering, Cisco System, Inc.

Jonah Alben
Senior Vice President GPU Engineering, NVIDIA

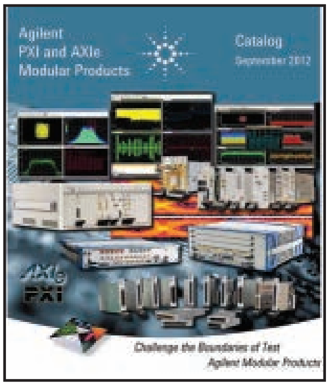


Mike Santorini
Business & Technology Fellow, National Instruments

Catalog Update

Modular Catalog

VENDORVIEW



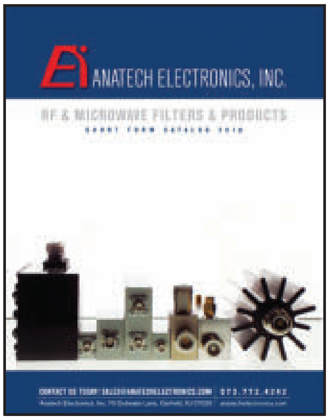
Agilent's updated modular catalog now includes all of the 16 recently introduced products, as well as enhanced sections on setup, operation and maintenance. Product categories include PXI vector signal generators and analyzers, PXI optical extenders, PXI chassis and controllers, PXI switches, AXIe digitizers and AXIe logic and protocol analyzers. The catalog provides a comprehensive overview of the modular products, ordering, support and warranty information. The modular catalog can be downloaded at http://cp.literature.agilent.com/litweb/pdf/5990-7367EN.pdf.

Agilent Technologies Inc.,

www.agilent.com.

2013 Filters Catalog

VENDORVIEW



Anatech Electronics has released its latest 2013 short-form catalog, which provides detailed descriptions of the company's broad line of RF and microwave filters, duplexers, LNA-filters, multi-band combiners, power dividers and many other products for commercial and military applications. The catalog describes Anatech's expertise in the design and manufacture of high-performance custom products as well as products available from its Web store, www.AMCrf.com. To download the catalog, go to www.anatechelectronics.com/catalogs.aspx.

Anatech Electronics,

www.anatechelectronics.com.

EMC & RF Testing Product Catalog

VENDORVIEW

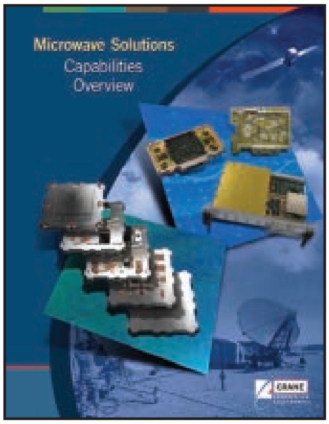
AR's new product catalog is now available from your local AR sales associate. The catalog is easy to use, with "find-it-fast" charts and color coding to help get right to whatever you need for RF and EMC testing. It is available for free download, either in full or by section at www.arworld.us.

AR RF/Microwave Instrumentation,

www.arworld.us.

Microwave Capabilities Catalog

VENDORVIEW



Crane Aerospace & Electronics Microwave Solutions launches the new microwave capabilities catalog that features a wide range of product solutions from component level devices to complex, advanced integrated microwave assemblies. Products are illustrated from major product areas and represent the breadth of technical capability of Crane. The company's microwave brands include Merrimac, Signal Technology and Polyflon. For more information on Crane Microwave Solutions, please visit www.craneae.com/mw.

Crane Aerospace & Electronics Microwave Solutions,

www.craneae.com.

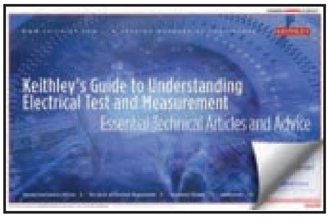
High Power RF Amplifiers Catalog

Ophir RF has a new high power RF amplifiers catalog available. The catalog is split into sections, including EMC/Test & Measurement, Communications, Medical MRI/NMR, Radar, Electronic Warfare, Custom Solutions, and Frankonia EMC Products. It includes an amplifier selection guide and a module selection guide. The catalog describes product application, system features, electronic characteristics, circuit protection and environmental characteristics, among other product information.

Ophir RF,

www.ophirrf.com.

Electrical Measurements Guide



Keithley's new e-handbook, *Keithley's Guide to Understanding Electrical Test and Measurement*, offers you online access to application notes, webinars, selector guides for choosing the optimal instrument, and overview and configuration of instrument options. From the most basic to very complex applications, there is one common element — the best possible measurements need to be made. This e-handbook has been compiled to help you analyze your applications and the various types of instruments that solve your test and measurement needs.

Keithley Instruments Inc.,

www.keithley.com.

AMTA 2013

The Antenna Measurement Techniques Association (AMTA) is a non-profit, international organization dedicated to the development and dissemination of theory, best practices and applications of antenna, radar signature and other electromagnetic measurement technologies.
Visit www.amta.org for more detail.

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The Ohio State University, Columbus, Ohio; Star Dynamics Corporation, Hilliard, Ohio; and Air Force Institute of Technology, Wright Patterson AFB, Ohio are proud to host the 35th Annual Meeting and Symposium of AMTA at the Hilton Easton in Columbus, Ohio from **October 6-11, 2013.** The host committee, lead by Professor Inder "Jiti" Gupta, cordially invites you to attend and participate in this annual event.

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Authors addressing advancements and innovations related to antennas, EM scattering and material measurements are invited to submit a 200-word abstract for possible presentation at the Symposium. The abstract submission deadline is May 1, 2013.

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Catalog Update

Supplier Line Card

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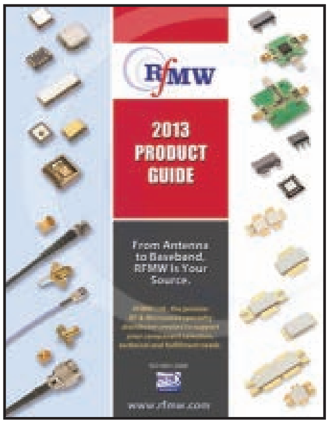

RFMW has released its latest supplier line card which highlights value added capabilities and includes a product matrix for easy identification of supplier product focus. RFMW's expanded line card includes three new suppliers plus additional divisions of existing suppliers. These additions enhance an already impressive offering of RF and microwave devices. The new line card is a comprehensive overview of the products supplied by this RF and microwave focused distributor. It is available in softcopy at www.rfmw.com/RFMWLinecard.pdf.

RFMW Ltd.,

www.rfmw.com.

Small Cell New Product Selector Guide

VENDORVIEW

Richardson RFPD announced the availability of its *Small Cell (Femto, Micro, Pico) New Product Selector Guide*. The October 2012 small cell selector guide includes the latest semiconductors, passive devices and frequency control devices for this dynamic application. Featuring more than 30 new products, the small cell selector guide is organized by product type, including amplifiers, detectors/controllers, antennas, dividers/combiners, RF couplers, modulators/demodulators and up/down converters. The guide is available on Richardson RFPD's website and is updated monthly.

Richardson RFPD Inc.,

www.richardsonrfpd.com.

Coax Switch Matrix Selection Guide

Teledyne Coax Switches has released its new *Coax Switch Matrix Selection Guide*. The guide features Teledyne's switch matrix capabilities with comprehensive descriptions of each matrix and additional options for users to tailor a matrix to their exact requirements. The guide features examples of matrix systems for markets including: military and defense, aircraft, industrial, SATCOM, advanced telecom, ATE, 4G, LTE and more. To find out how to specify your matrix, order or download the *Coax Switch Matrix Selection Guide* online at www.teledynerelays.com/lit-request.asp.

Teledyne Coax Switches,

www.teledyne-europe.com.

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Innovations in EDA
Presented by: Agilent Technologies
Freescale's Power Amplifier Design Methodology Innovations
Available On Demand after 1/10/13

Agilent in Aerospace/Defense
RF/uW Measurement Uncertainty: Calculate, Characterize, Minimize
Live webcast: 1/17/13, 1:00 PM ET

FieldFox Handheld Analyzers
Presented by: Agilent Technologies
Techniques for Precise Time Domain Measurement in the Field
Live webcast: 1/23/13, 1:00 PM ET

Agilent in Wireless Communications Series
Moving Forward to LTE-Advanced with Heterogeneous Networks
Live webcast: 1/24/13, 1:00 PM ET

RF and Microwave Education Series
Presented by: Agilent Technologies
Signal Generator Fundamentals and New Applications
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- Spur-Free Switching Power Converters for Analog and RF Loads
- Mixers and Frequency Conversion

Technical Education Training Series
- VCO Fundamentals
- RF PCB Design
- Introduction to Antenna Simulation with COMSOL Multiphysics
- Radar Fundamentals II - Pulse Doppler Radar

CST Webinar Series
- Simulation of EMI in Hybrid Cabling for Combining Power and Control Signaling
- Chip/Package/Board: Constraint Driven Co–Design
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- 10-Steps to Determine 3G/4G IP Data Throughput
- Addressing Measurement Challenges of 160 MHz 802.11ac MIMO
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Optimize Wireless Device Battery Run-Time Series
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- Impact of the Battery, Its Management, and Its Use
- Innovative Measurements for Greater Insights

FieldFox Handheld Analyzers Series
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- Techniques for Precise Cable and Antenna Measurements in the Field
- Techniques for Precise Interference Measurements in the Field

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Notch Filter

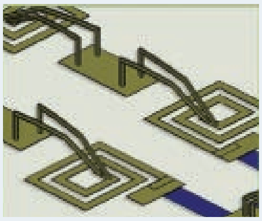
VENDORVIEW

Model AS816N335 is an extremely high Q notch filter designed for 800 MHz GSM applications that has extremely sharp transition characteristics from the stopband to the passbands and extremely high rejection of -70 dB. It has a notch center frequency of 816.5 MHz, notch of 816 to 817 MHz, low-side passband beginning at 809 MHz and high side passband beginning at 821 MHz. Passband return loss is at least 18 dB. The filter measures 17.2" × 3.1" × 2.2" and uses female Type-N connectors.

Anatech Electronics,
www.anatechelectronics.com.

Antenna Synthesis Software

VENDORVIEW



AWR, developer of the antenna synthesis product Antenna Magus, introduced Antenna Magus Version 4.1, which adds four new antenna types: axial choke horn with dielectric lens, offset-fed Gregorian reflector, Cassegrain reflector and egg-beater antenna. The new version also adds new tools, including a radar cross section tool, passive remote sensing tool and two-port network conversion tool. With this latest release, the planar portfolio of designs that connect to AWR's Microwave Office™ software and AXIEM® 3D planar EM simulator now supports more than 50 topologies.

AWR Corp.,
www.awrcorp.com.

Radar Synthesizer

The Bench-Forge Colt 5 to 6 GHz UNII/DFS radar synthesizer provides an inexpensive solution for the testing and development of DFS-enabled wireless products. It provides engineers with desktop capability to prepare for DFS product certification. Colt generates FCC Type 1-6, ETSI and Japanese radar types, as well as custom types. It connects to either Linux or Windows-based systems via RS-232. Base price is $1495.00 (price includes Colt, antenna and USB-to-RS-232 adapter.)

BenchForge,
www.benchforge.com.

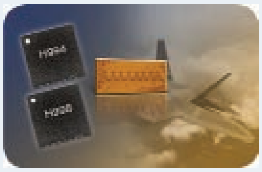
Antenna System Module

Ethertronics unveiled EtherModule 1.0, a turnkey, plug-and-play, active antenna system module combining Ethertronics' advanced antenna architecture and EtherChip 1.0 tunable capacitor on a printed circuit board for easy integration. EtherModule 1.0 has a typical dynamic range of 20 dB to deliver maximum performance across a wide range of frequencies and use cases. Given the combination of closed loop functionality with a proprietary algorithm integrated in conjunction with a microprocessor, the module is capable of dynamically sensing and optimizing the antenna system, without external control signals from the device.

Ethertronics,
www.ethertronics.com.

Power Amplifier

VENDORVIEW



Hittite Microwave launched a new PA that is ideal for microwave radio, EW, ECM and radar applications to 28 GHz. The HMC994LP5E is a GaAs MMIC PHEMT distributed power amplifier that operates between DC and 28 GHz. The amplifier provides 13 dB of gain, +29 dBm of saturated output power, and 23 percent PAE from a +10 V supply. With up to +38 dBm output IP3, the HMC994LP5E is ideal for high linearity applications in military and space as well as point-to-point and point-to-multi-point radios.

Hittite Microwave Corp.,
www.hittite.com.

GaN HEMT

IGN2729M500 is an internally pre-matched, GaN high electron mobility transistor (HEMT). This part is designed for S-Band radar applications operating over the 2.7 to 2.9 GHz instantaneous frequency band. Under 300 µs/10 percent pulse conditions, it supplies a minimum of 500 W of peak output power with typical performance of 560 W, typically 12 dB gain and over 60 percent efficiency. Specified operation is with Class AB bias. When appropriately rated, it is operable under a wide range of pulse widths and duty factors.

Integra Technologies Inc.,
www.integratech.com.

Panel Antenna

L-com announced its new HyperLink 2.4 GHz 14 dBi three element, dual polarized panel antenna. The HG2414DP-3NF provides combined vertical and horizontal polarization with high gain in a single enclosure. Compatible with IEEE 802.11 b/g/n standards, it combines three separate antennas (two vertically and one horizontally polarized multi-patch) in a single housing. It is a professional quality antenna designed primarily for MIMO point-to-multipoint and point-to-point applications. The triple feed system makes it ideal for use with APs and routers with 1, 2 or 3 antenna ports.

L-com Inc.,
www.l-com.com.

Cassegrain Antenna

mWAVE Industries introduced model number RPCS2.3-250-42O, a K/Ka-Band Cassegrain antenna. The main reflector is a precision 28" diameter lightweight composite with integral mounting hub. The primary radiator is a corrugated conical horn providing exceptional polarization discrimination performance, sidelobe suppression and beam symmetry. Rx operating frequency range is 22.55 to 23.55 GHz. Tx operating frequency range is 25.25 to 27.50 GHz. Input is a WR-42 flat flange with o-ring. The polarization is single CP, switchable. Polarization is electronically switchable between LHCP and RHCP via remote control using a 24 V DC waveguide switch.

mWAVE Industries LLC,
www.mwavellc.com.

NFC Antenna

Pulse Electronics introduced a near field communications antenna that enables mobile phones to read data from a distance of up to 40 mm. The planar ferrite sheet-based antenna has dimensions of 35 × 50 mm with a minimum thickness of 0.30 mm, including the ferrite/adhesive/antenna flex layers. The magnetic field strength can be optimized by the type and thickness of the ferrite material and the design of the radiator pattern. The antenna meets EMVco specifications ensuring global interoperability and compatibility of chip-based payment cards and acceptance devices.

Pulse Electronics Corp.,
www.pulseelectronics.com.

Microwave Antenna

Featuring a wind-tunnel tested design suited for both tight urban locations and rugged outposts, the SB6-W60B microwave antenna offers a superior radiation pattern for consistent performance with less interference. It has a compact design and offers reliable frequency coordination and high frequency re-use. The SB6-W60B covers the full 6 GHz frequency band of 5.925 to 7.125 GHz and is available in single and dual-polarized models with the option to upgrade from single to dual polarization and change frequencies in the field.

Radio Frequency Systems (RFS),
www.rfsworld.com.

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Get the performance of semi-rigid cable, and the versatility of a flexible assembly. Mini-Circuits Hand Flex cables offer the mechanical and electrical stability of semi-rigid cables, but they're easily shaped by hand to quickly form any configuration needed for your assembly, system, or test rack. Wherever they're used, the savings in time and materials really add up!

Excellent return loss, low insertion loss, DC-18 GHz. Across their entire bandwidth, Hand Flex cables deliver excellent return loss (>26 dB typ for up to 50" runs) and low insertion loss (0.2 dB typ at 9 GHz for a 3-inch cable). So why waste time measuring and bending semi-rigid cables, when you can easily install a Hand Flex interconnect?

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Standard lengths in stock, custom models available. Standard lengths from 3 to 50" are in stock for same-day shipping. You can even get a Designer's Kit, so you always have a few on hand. Custom lengths, or two-right-angle models, are also available by preorder. Check out our website for details, and simplify your high-frequency connections with Hand Flex!

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U.S. Patents 7739260, 7761442

IF/RF MICROWAVE COMPONENTS

New Products

Components

Cable Assemblies

VENDORVIEW

Florida RF Labs has expanded its Lab-Flex® family of cable assemblies to include two new 50 GHz designs. They are ideal for high frequency test applications and high-density interconnects where insertion loss and stability over temperature are concerns. As with all Lab-Flex products, these assemblies offer > 90 dB of shielding effectiveness and both offer a wide range of connectors including SMA, 2.4mm and 2.92mm interfaces in various configurations. The Lab-Flex product family currently consists of five cable diameters: 0.100", 0.125", 0.200", 0.290" and 0.335".

Florida RF Labs,
www.emc-rflabs.com.

Phase Shifter

Herley General Microwave's digitally programmable model 7929 phase shifter is an ideal solution for today's military airborne systems. It operates over the 18 to 40 GHz frequency range, provides 360° phase shift with accuracy of < ±15° and switching time of < 500 nanoseconds. Phase control via 10 Bit TTL providing high resolution of 0.35° and guaranteed monotonic.

Herley General Microwave,
www.herley.com.

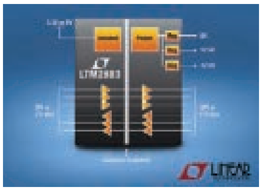
Highpass Filter

Integrated Microwave offers a high-frequency true elliptic function highpass filter. This small-profile filter offers a nominal passband insertion loss of 0.7 dB at 5.2 to 13 GHz. This superior rejection provides 20 dB at 4.9 GHz, and –40 dB nominal DC to 4.8 GHz, with a 3 dB cutoff at 5.15 GHz. Performance is comparable to a suspended substrate, but at one-quarter the size and cost.

Integrated Microwave Corp.,
www.imcsd.com.

Digital Isolator

VENDORVIEW



Linear Technology introduced the LTM2883, a six-channel SPI/Digital or I²C digital µModule® isolator with triple rail regulated power for 3.3 and 5 V systems. The LTM2883 breaks ground loops by electrically separating communications signals, isolating the logic level interface on each side of an internal inductive isolation barrier that withstands a very large common-mode voltage range up to 2500 V RMS. The LTM2883's low EMI isolated DC-DC converter powers the communications interface and provides adjustable 5, +12.5 and -12.5 V supply outputs.

Linear Technology Corp.,
www.linear.com.

In-Series Adapter

Mesa Microwave introduced P/N MMCNPPA plug-to-plug adapter in stainless finish at 50 Ω. Mesa Microwave "In-Series" adapters are available in 50 and 75 Ω. The company's adapters feature stainless steel construction for a more precise interface, and it also manufactures precision adapters with higher frequency ranges. Visit its website to learn more about its full line RF components such as precision coaxial connectors, cable assemblies and electronic components.

Mesa Microwave Corp.,
www.mesamicrowave.com.

Jumper Cables

Microlab has extended its line of JP/JR/JS series jumper cables. With an operating range of DC to 3 GHz, these cables are ideal for all telecommunication applications in the frequency bands between 380 and 2700 MHz. They are attractively priced and "Microlab Certified™." Microlab's jumper cables are available with N and DIN 7/16 connectors, both as straight and rectangular types. Available connector combinations are: JP straight (m)/straight (m), JR straight (m)/rectangular (m), JS rectangular (m)/rectangular (m).

Microlab,
http://fxr.com.

Extra Flexible Waveguide

Extra flexible waveguide is available in both standard and custom designed configurations, spanning frequencies from 10 to 50 GHz. This product is ideal for applications that require repetitive or wide-angle flexure. The interior is silver plated for minimal insertion loss. Microtech manufactures flexible waveguide from WR10 (110 GHz) down to WR650 (1.12 GHz). The company has been serving customers for 58 years, developing different sizes and types of flex to meet customers' specifications.

Microtech Inc.,
www.microtech-inc.com.

Low PIM Connectors

Pasternack's high performance low PIM connectors are designed to fit most commercially available ½" corrugated copper and aluminum cables. They are available in 7/16 DIN and Type N series with male and female interfaces. Pasternack's custom length assemblies using these new low PIM connectors are made to order and ship the same day. Each PIM connector body is plated with a tri-metal Abaloy coating that produces a very durable surface with good corrosion protection while providing superior electrical conductivity and exceptional PIM performance.

Pasternack Enterprises Inc.,
www.pasternack.com.

Dual Balun

Response Microwave announced the availability of its new dual balun family for use in converting E1/T1 channels from 75 Ω coax to two 120 Ω twisted pair signals. Part of the Compel series of connectivity products, the new units operate between DC and 3 MHz and offer return loss per CCITT G703, signal balance according to ETS300166 and support E1 data rates to 2.048 Mpbs and E2 rates to 8.448 Mbps. Configurations are available with 1.0/2.3 coax to RJ45 and BNC coax to RJ45.

Response Microwave Inc.,
www.responsemicrowave.com.

Digital Step Attenuators

VENDORVIEW

RFMD's new RFSA2644/2654 6-bit digital step attenuators (DSA) feature high linearity over their entire 31.5 dB gain control range with excellent step accuracy in 0.5 dB steps. They are programmed via a serial mode control interface that is both 3 and 5 V compatible.

They also offer a rugged Class 1C HBM ESD rating via on-chip ESD circuitry. The MCM package is footprint-compatible with most 24-pin, 4 × 4 mm, QFN packages.

RF Micro Devices,
www.rfmd.com.

Wireless Transceivers

Specialized wireless transceivers from Ritron provide OEMs and integrators with wireless connectivity and COTS convenience in a compact, cost-effective package. Available in various configurations – including RF transceivers and radio modems – they permit integration into systems demanding utmost performance in congested frequency environments. A small footprint minimizes space requirements, while all components are placed on the top side of a single PCB for mechanical rigidity and increased protection against damage. Narrow band (12.5 kHz) and very narrow band (6.25 kHz) models are available.

Ritron Inc.,
www.ritron.com.

Adjustable Delay Line

RLC Electronics' manually adjustable delay line (phase shifter) offers continuous adjustment of electrical delay over the frequency range of DC to 40 GHz. Adjustment is through a multiturn, locking shaft with approximately 5 picoseconds per turn. Low insertion loss and VSWR are maintained throughout the adjustment range. The unit

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comes with a choice of male or female 2.92 mm connectors. It has a 50 Ω impedance, 5 W average power rating and a -55° to +85°C temperature range.
RLC Electronics Inc.,
www.rlcelectronics.com.

Connectors

Times Microwave Systems announced its new non-solder two-piece EZ 7/8 EIA flange, 7/16 DIN and Type N connectors for LMR-1200-DB and LMR-1200-FR flexible low loss 7/8" 50 Ω coaxial cables. These high quality connectors utilize a non-solder spring finger center conductor contact and clamp-style outer contact attachments. The total number of connector parts has been reduced from six pieces to only two pieces making them ideal for field installations. Non-solder EZ style connectors are also available for most LMR® cable types and sizes.
Times Microwave Systems,
www.timesmicro.com.

Amplifiers

SSPA Module

Comtech PST introduced model BME69189-20, a GaN-based, 6 to 18 GHz, 20 W RF solid state power amplifier. It features high efficiency (12.5 percent typical), full power across the entire bandwidth, low harmonic distortion, and is compact and lightweight (6.56" × 3.50" × 0.84", 5 lbs.). It has a noise power output of –105 dBm/Hz typical and an operating temperature of –40° to +55°C Baseplate (external heatsink required).

Comtech PST,
www.comtechpst.com.

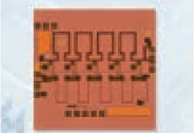
Traveling Wave Tube Amplifiers

Comtech Xicom announced an expanded 12.75 to 14.5 GHz frequency coverage option for its Ku-Band TWTAs. Its new line of high-efficiency, antenna-mount TWTAs, including models XTD-400KHE and XTD-750KHE, are capable of operating across this entire band. Xicom's model XTD-1250KL antenna-mount amplifier, as well as the new XTRT-1250KL rack-mount amplifier with touch screen control interface, are also available with the extended wideband coverage. In support of this new bandwidth, Comtech Xicom is now offering 400, 750 and 1250 W TWTAs that provide full spec-compliant performance over the expanded band.
Comtech Xicom Technology Inc.,
www.xicomtech.com.

Amplifier Die

VENDORVIEW

Custom MMIC is offering a new device from its growing MMIC library of standard products. The CMD173 is a wideband GaAs MMIC distributed amplifier die for applications from DC to 20 GHz. This device delivers greater than 15 dB of gain with a corresponding output 1 dB compression point of +18 dBm, and a noise figure of 1.5 dB at 8 GHz. The CMD173 is an all-positive bias design, thus eliminating complicated and costly sequencing circuits while also simplifying board layout.



Custom MMIC,
www.custommmic.com.

Amplifier Module

VENDORVIEW

Richardson RFPD announced immediate availability of a new high power amplifier module from Empower. The 1163/BBM2E3KLO is a 20 to 520 MHz, 7" × 4" × 1.5" amplifier that is guaranteed to deliver 125 W output power and related RF performance under all specified temperature and environmental conditions. It uses high power LDMOS transistors and offers built-in control and monitoring, with protection functions that include non-volatile memory for event recording and factory setup recovery features.

Empower RF Systems Inc.,
distributed by Richardson RFPD Inc.,
www.empowerrf.com.

Waveguide LNAs

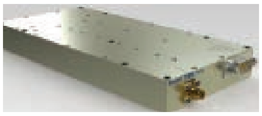
VENDORVIEW

Model AMFW-6S-12601520-90-WR62 is a very low noise, high dynamic range, weatherproof Ku-Band waveguide front end, operating from 12.65 to 15.2 GHz. Includes a pressure sealed WR62 waveguide input and SMA (F) output. The LNA is lightweight (approximately 270 g) with a small profile (2.1" × 1.31" × 1.31") footprint. The aluminum alloy housing is sealed against most severe environmental conditions. This LNA includes reverse voltage, over current and over temperature protection in addition to full internal regulation.

MITEQ Inc.,
www.miteq.com.

GaN Power Amplifier

RADITEK's high efficiency broadband GaN power amplifier delivers a minimum saturated output power (Psat) of 50 W over the frequency range 20 to 1000 MHz. Standard specifications: operating voltage 28 V DC, supply current at Pout = 50 W is 6 amps. Dimensions (excluding heatsink): 188 × 91.5 × 21.3 mm, weight = 800 g. RF connectors in/out: SMA female, interface connector: 9 way D type.

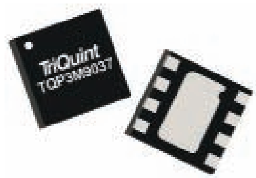


RADITEK,
www.raditek.com.

LNA

VENDORVIEW

RFMW announced design and sales support for TriQuint Semiconductor's TQP3M9037, an internally matched, low noise amplifier combining a 0.4 dB noise figure with 20 dB gain and 35 dBm OIP3 in a 2 × 2 mm DFN package. This LNA provides an instantaneous bandwidth of 1500 to 2700 MHz and requires only bypass/blocking capacitors and a bias inductor for operation, no matching components are required. In addition, TriQuint engineering has integrated shut-down biasing capability to allow for TDD applications.



TriQuint Semiconductor,
distributed by RFMW Inc.,
www.triquint.com.

Sources

Miniature Frequency Synthesizers

VENDORVIEW

AtlanTecRF's miniature single phase-locked loop frequency synthesizers exhibit fundamental output frequencies up to 12.5 GHz and multiplied output frequencies to 25 GHz. With control via a choice of either RS485 or Ethernet, each unit can be taken through its frequency range in 1 kHz steps with 5 ms switching speed. In addition to output frequency range, these synthesizers include the choice of internal or external reference and input power is taken from a +5 V DC supply.

AtlanTecRF,
www.atlantecrf.com

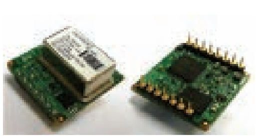
Voltage Controlled Oscillator

Crystek's CVCO55CC-2610-2625 VCO operates from 2610 to 2625 MHz with a control voltage range of 0.5 to 4.5 V. This VCO features a typical phase noise of –120 dBc/Hz at 10 KHz offset and has excellent linearity. Output power is typically +7 dBm. Engineered and manufactured in the USA, the model CVCO55CC-2610-2625 is packaged in the industry-standard 0.5" × 0.5" SMD package. Input voltage is 8 V, with a maximum current consumption of 30 mA. Pulling and pushing are minimized to 2 MHz and 0.2 MHz/V, respectively.

Crystek Corp.,
www.crystek.com.

Frequency and Timing Reference

Jackson Labs Technologies announced the availability of its breakthrough LC_XO 10 MHz frequency and timing reference which integrates a GPS receiver, power supplies, and an ovenized, disciplined crystal oscillator into a sub 1" × 1" footprint. The LC_XO time and frequency reference is a highly integrated global positioning system disciplined oscillator (GPSDO) using a 50 channel GPS receiver with WAAS to discipline an OCXO or TCXO to typically better than 0.5 ppb frequency accuracy.



Jackson Labs Technologies Inc.,
www.jackson-labs.com.

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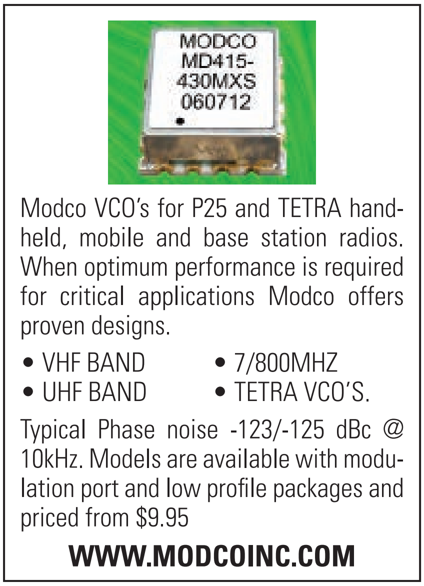

New Products

Bench Test Frequency Synthesizers

Micro Lambda Wireless announced the production release of bench test frequency synthesizers covering the frequency range of 2 to 20 GHz in customers specified frequency bands. Utilizing the MLSP-Series of frequency synthesizers, units provide +10 to +13 dBm output power levels and are specified over the standard lab environment of +15° to +55°C temperature range. All units consist of a frequency synthesizer, AC power supply, heat sink with fan, key pad, tuning knob, frequency display and driver circuitry.

Micro Lambda Wireless Inc.,
www.microlambdawireless.com.

Amplified Noise Source

NoiseWave announced the immediate availability of the new NoiseWave NW6G-B/SM surface mount amplified noise source. The NW6G-B/SM is an ideal choice for surface mount PCB applications. Offering broadband frequency coverage from 200 kHz to 6 GHz, it features at least 30 dB ENR with typical flatness of ± 2.5 dB or better. All bias circuitry is included so operation is simple and repeatable. The unit draws only 10 mA current from +12 V DC.

NoiseWave,
www.noisewave.com.

DRO

VENDORVIEW

PMI model no. PIA-10G-CD-1 is a 10 GHz integrated, dielectric resonator (DRO) module with three outputs, each having a 0° to 360° analog controlled, variable phase shifter and 0 to 10 dB analog controlled, variable output control capability on each of the outputs. This model provides a low harmonic output of –50 dBc typical and an output power level of +19 dBm typical. This DRO operates on ±15 V DC and is supplied in a compact package measuring 6.25" × 2.5" × 1.0". Other frequency ranges are available.

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

Fixed Frequency Synthesizer

Z-Communications announced the new RoHS compliant fixed frequency synthesizer model SFS4000C-LF for satellite communications and test equipment. The SFS4000C-LF is a single frequency synthesizer that is phase locked at 4000 MHz while using a 10 MHz reference. This coaxial resonator PLL features remarkable phase noise of –102 dBc/Hz at 10 kHz offset and typical sideband spurs of –65 dBc. The low phase noise device is designed to operate over the extended commercial temperature range of –25° to 90°C.

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

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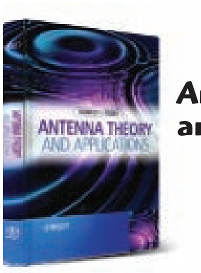

Antenna Theory and Applications

Hubregt J. Visser

This book covers fundamental antenna theory and shows how to apply this in practice. It is derived from an elective course on antenna theory given at Eindhoven University of Technology. The author discusses electromagnetic radiation and antenna characteristics such as impedance, radiation pattern, polarization, gain and efficiency. The book provides readers with the necessary tools for analyzing complex antennas and for designing new ones. A refresher chapter on vector algebra, including gradient, divergence and curl operation is included. Throughout the book there are examples of employing the derived theory and all chapters are concluded with problems, giving readers the opportunity to test their acquired knowledge.

The book is accompanied by a website containing solutions to the problems and CST Microwave Studio® modeling files. However, the examples and design case studies are described in such a way that any other full-wave analysis software suite could be used if the reader has another preference. In the examples, the theory derived is used to assess the dimensions of an initial, realistic antenna that is fine-tuned to the desired characteristics using the full-wave analysis software suite.

This book is a good reference for advanced students in antenna and RF engineering, wireless communications, electrical engineering, radio engineers and other professionals needing a reference on antenna theory. It will also be of interest to advanced or senior radio engineers, designers and developers as a practical guide and reference. It assumes knowledge of electromagnetic theory and vector analysis.

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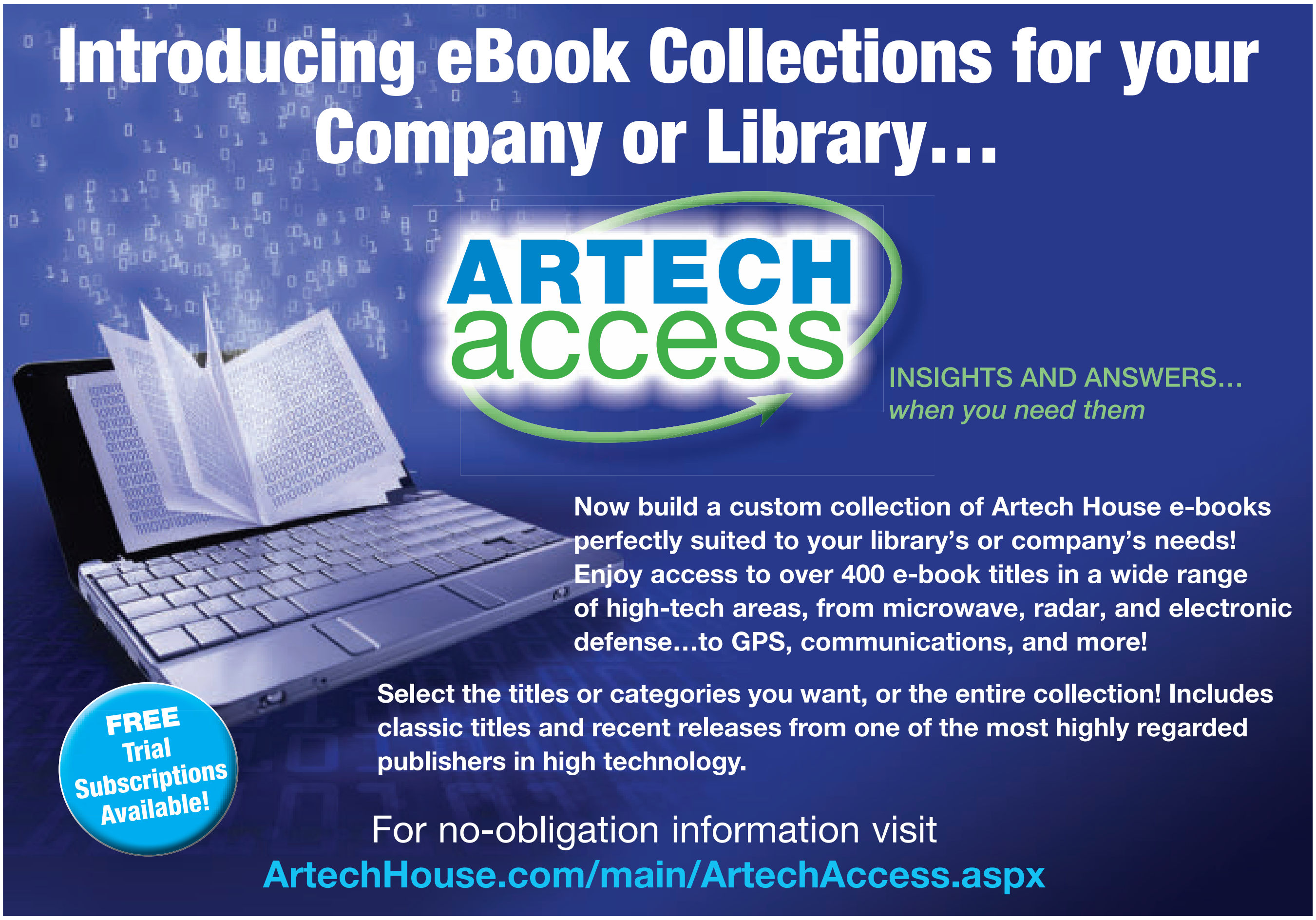

IEEE COMCAS 2013

The International IEEE Conference on Microwaves, Communications, Antennas and Electronic Systems

David Intercontinental Hotel, Tel Aviv, Israel, October 21-23, 2013

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Call for Papers

IEEE COMCAS 2013 continues the tradition of providing a multidisciplinary forum for the exchange of ideas, research results, and industry experience in the areas of microwaves, communications, antennas, solid state circuits, electromagnetic compatibility, electron devices, radar and electronic systems engineering. It includes a technical program, industry exhibits, and invited talks by international experts in key topical areas.

The conference will take place on October 21-23, 2013 in Tel Aviv, Israel. The David Intercontinental Hotel on the Mediterranean sea offers an excellent venue for networking and the candid exchange of ideas.

Papers are solicited in a wide range of topics including:

Aeronautical and space applications and challenges	Microwave and millimeter wave circuits and technologies
Analog/digital RF circuits and systems	Microwave imaging and tomography
Antennas (components, modeling, micro & macro scale)	MIMO (multiple antenna systems for communications and radar)
Automotive and transportation radar and communications	Modulation and signal processing technologies
Biomedical applications (body area systems, scanning devices, telemedicine)	Nanotechnologies and applications
CAD techniques for microwave and communications devices	Optical/wireless convergence and integration; radio over fiber
Circuit theory, modeling and applications	Radar signal processing
Cognitive radio and spectral sharing technologies	Radar techniques, systems and applications
Electromagnetic compatibility	RFID devices, technologies, systems and applications
Fifth generation mobile communication	RF power amplifiers and devices
Filters and Multiplexers	Sensor networks and technologies
First responder and military communication, sensing and information retrieval systems	Software-defined radio and multiple air interface devices
Environmentally sensitive design ("green" communications, electromagnetic, and antenna systems)	Solid-state devices, RFICs
MEMS modeling, devices and applications	Spatial coding
Microcell, picocell and femtocell devices, systems and applications	Terahertz technologies and systems

Regular oral presentations will be 20 min. in length; there will also be Poster sessions.
All submitted papers will be peer reviewed and assessed on key accomplishments, technical contribution, and advancement of the state-of-the-art, originality and interest to the attendees. Accepted papers will be published in the COMCAS2013 Proceedings which will be available through IEEE Xplore® after the conference.

Submission of papers:

English-language manuscripts, no longer than five pages including figures and references, must be submitted using the IEEE MS Word template available at
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See author instructions at **www.comcas.org**

Important deadlines:

Submission of manuscript:	April 1, 2013
Notification of acceptance/rejection:	June 1, 2013
Submission of final camera-ready paper:	August 1, 2013
Early bird (lower cost) registration:	August 15, 2013

Technical Exhibition:

The technical program will be complemented with a technical exhibition, which will be held on October 21-22, 2013 offering companies and agencies a unique opportunity to visit Israel and present related products and services in display and printed advertisement.
For further details please contact the Conference Secretariat.

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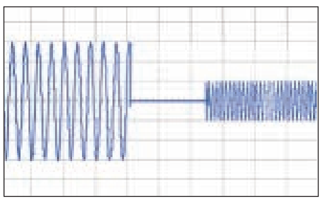

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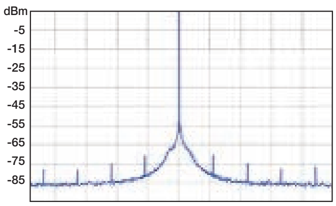

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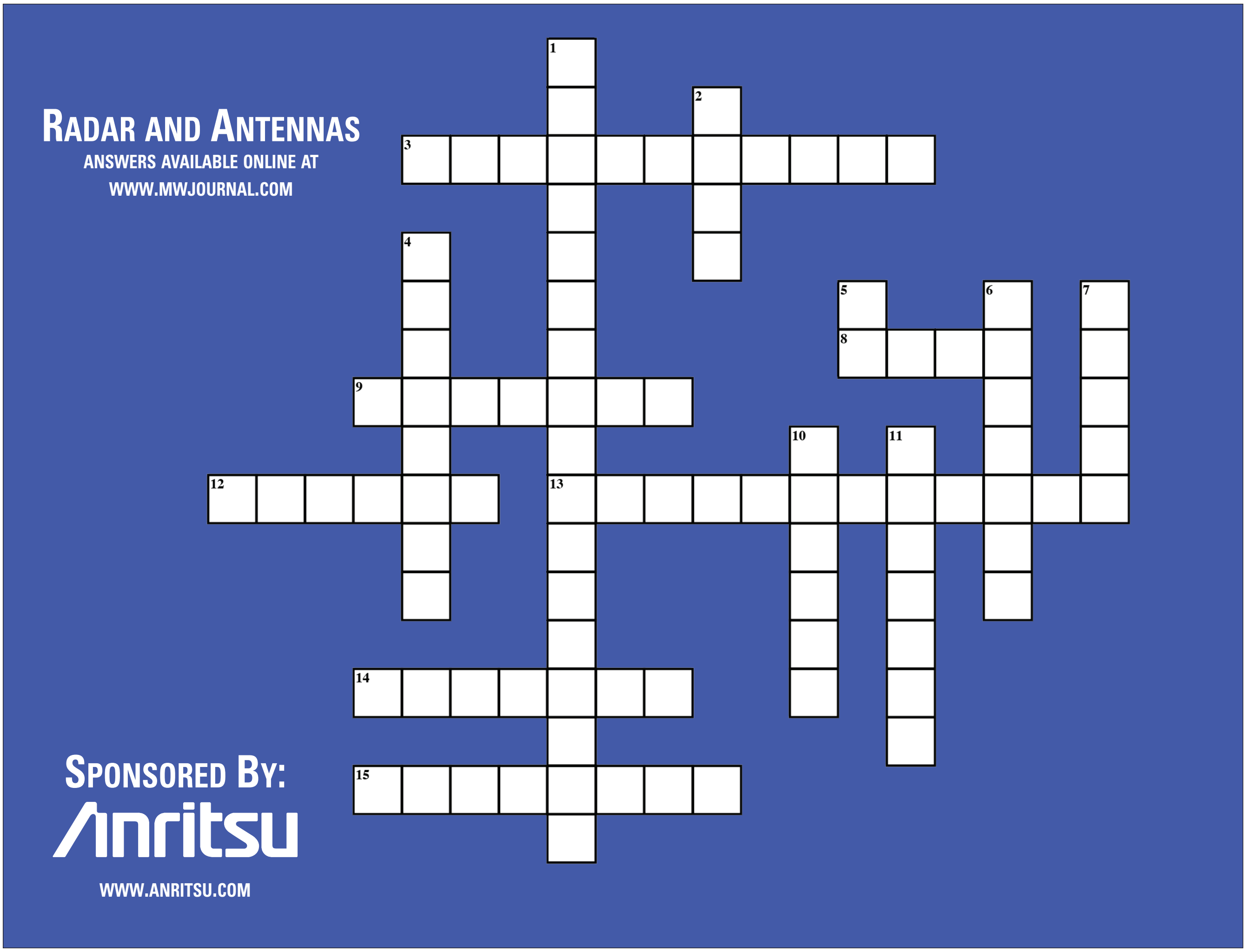

ACROSS

3 An antenna in which all elements, both active and parasitic, are in one plane (2 words)

8 Generally it would not be efficient to use the individual elements of an array as the ______ elements

9 Type of radar that does not have its own transmitter but exploits one or more transmitters of opportunity located in the area

12 The main advantage of employing passive radars for military or defense uses is that they are _______

13 The point along in a spiral antenna where significant radiation takes place (2 words)

14 Advances in ________ electronics have recently enabled practical passive radar systems

15 The most widely used spiral antenna type is the ______ ______ planar spiral with metal cavity housing (2 words)

DOWN

1 A form of radar whose defining characteristic is its use of relative motion, between an antenna and its target region (2 words)

2 A highly directional and selective shortwave antenna consisting of a horizontal conductor of one or more dipoles

4 For search, _______-MIMO processing should be used

5 SELEX has developed a dual-band passive radar using signals from the ______ and DVB-T bands

6 The spiral is typically fed by an RF ___________connector

7 The _______ design is one of the most critical elements for a high-performance spiral in an EW or ESM systems

10 MIMO is not generally efficient for track, only for ________

11 Using subarray-MIMO ________ the computation throughput

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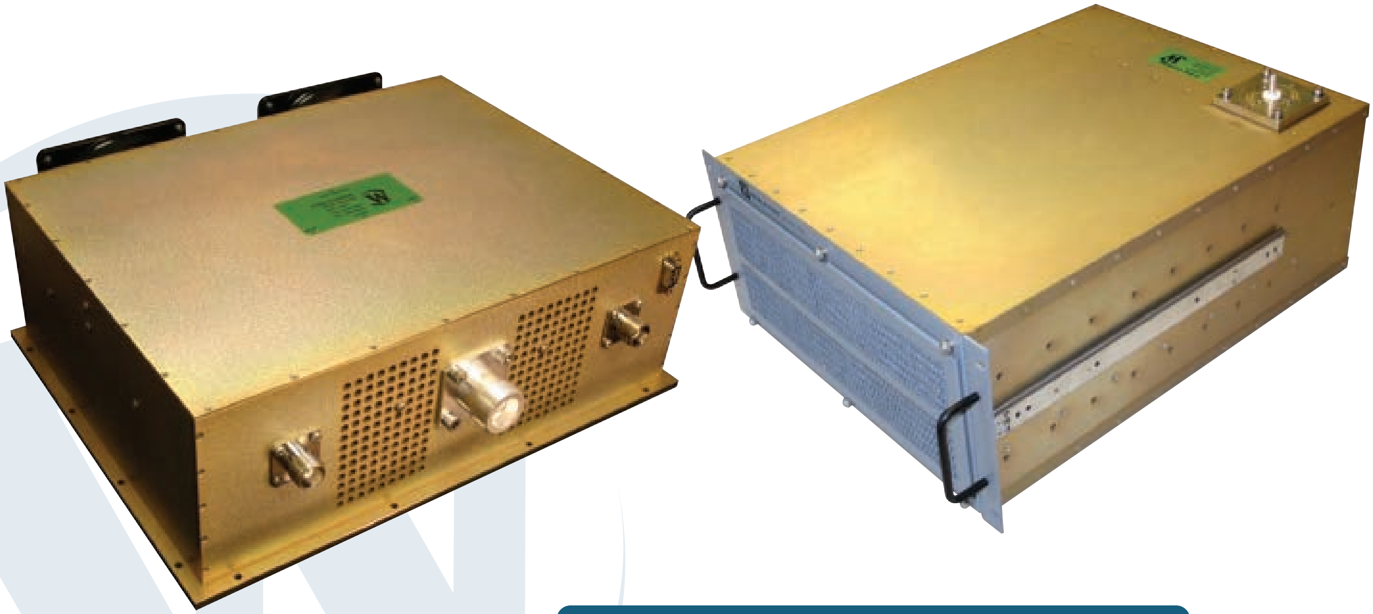

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D8969	2-Way	1.5-30	12,500	0.2	1.25	20	17 x 17 x 8
D6139	4-Way	1.5-32	5,000	0.25	1.25	20	13 x 11 x 5
D6774	4-Way	1.5-32	20,000	0.3	1.20	20	21 x 17.25 x 11
D6846	6-Way	1.5-30	4,000	0.35	1.35	20	3 U, 19" Rack
D8421	8-Way	1.5-30	12,000	0.3	1.30	20	22.5 x 19.5 x 8.75
D7685	4-Way	2-100	2,500	0.5	1.30	20	14.75 x 13 x 7
D2786	4-Way	20-150	4,000	0.5	1.35	20	18 x 17 x 5
D6078	2-Way	100-500	2,000	0.25	1.20	20	13 x 7 x 2.25
H7521	2-Way (180°)	200-400	2,500	0.3	1.30	20	15 x 10 x 2
D7502	2-Way	400-1000	2,500	0.25	1.20	NI*	9.38 x 3.5 x 1.25

*NI = No Isolating Terminations

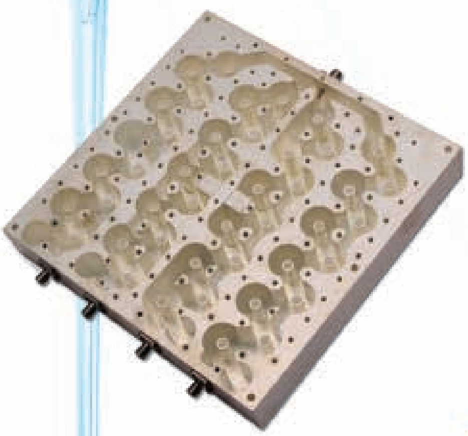
Our Patented, Low Loss Combiner designs tolerate high unbalanced input powers, while operating into severe Load Mismatch conditions.

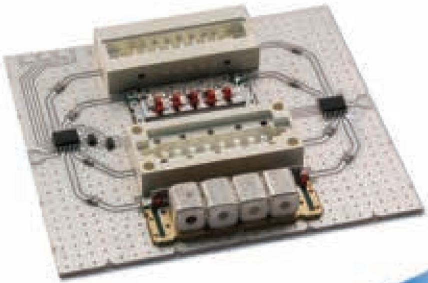
Semiconductors | First Response | Medical | In-Building | Military Comm and EW

Lark Engineering Co.™
THE FILTER SOURCE

Product Specification Guide

- Filters
- Multiplexers
- Switch Filter Banks
- Digital Control Filters
- Multi-Function Assemblies





Lark Engineering Co.™
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www.larkengineering.com

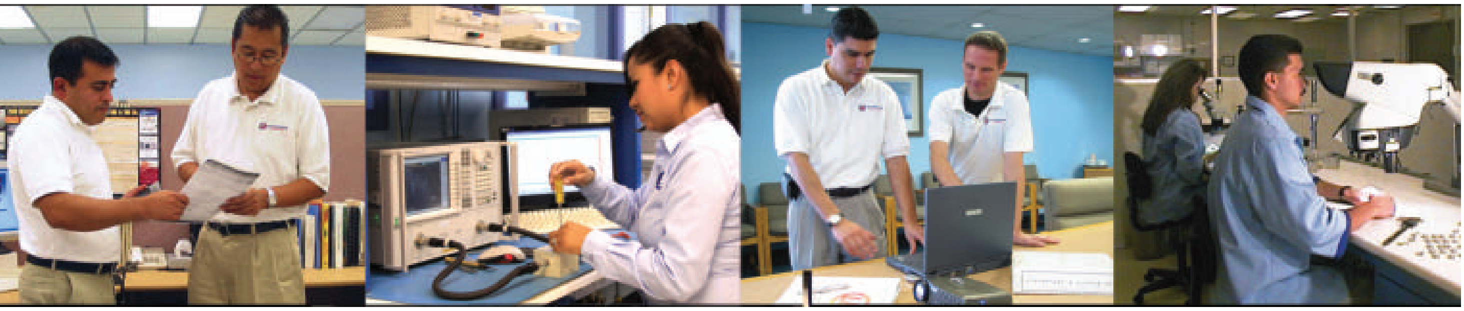
ISO 9001:2008
ISO 14001:2004

LARK ENGINEERING CO.

A Division of Baier and Baier, Inc.

Lark Engineering is a leading supplier of RF and Microwave filters with ISO 9001 and ISO 14001 certifications. The company was established in 1986 with the goal to design and manufacture quality products to meet or exceed the customer's individual needs and requirements. Currently Lark Engineering's products are being utilized in major digital and analog wireless devices ranging in use from communications systems to test equipment and military systems. Lark Engineering also produces filters for GPS, Cellular, ISM, PCN, PCS and many other wireless applications. For each customer, Lark Engineering is committed to providing the very best quality of filters and is dedicated to meeting our customer's Microwave and Radio Frequency filter needs. Our commitment to quality and customer service has been a cornerstone of the company since its inception.

Today, with an ever-changing industry, Lark Engineering continues to be the leader in RF and Microwave filters by focusing on design, quality and customer service. We offer an extensive product mix with filters and Multiplexers that satisfy requirements from 1 MHz to 40 GHz. Our web based filter design tool allows you to design Band Reject, Surface Mount Combline, High Power Ceramics and many other filters. Many of our filters can be sampled in as little as 10 days.



Lark Engineering Standard Filter Capabilities include the following:

BANDPASS	CENTER FREQUENCY RANGE	3db BW (% OF Fc)	CONFIGURATION
MC	1 – 6000 MHz	2 – 75	Miniature PCB Mount / SMA
SMC	5000 – 15000 MHz	3 – 30	SMT Combline
MS	1 – 6500 MHz	2 – 75	SMT Leadless
SD	200 – 6000 MHz	1 – 10	SMT Leadless Ceramic
SDP	350 – 2250 MHz	3 – 10	High Power Ceramic
3B	1000 – 32000 MHz	1 – 50	Combline Coaxial Connecters
4B	1000 – 32000 MHz	1 – 50	Combline Coaxial Connecters
2C	50 – 500 MHz	1 – 2.5	Cavity
3C	400 – 2500 MHz	0.2 – 5	Cavity
4C	800 – 2500 MHz	0.2 – 5	Cavity
5C	800 – 4000 MHz	0.2 – 5	Cavity
6C	2000 – 9000 MHz	0.2 – 5	Cavity

BAND REJECT	CENTER FREQUENCY RANGE	3db BW (% OF Fc)	CONFIGURATION
SDN	250 – 3500 MHz	1 – 10	SMT Leadless Ceramic

HIGHPASS	CUT OFF FREQUENCY RANGE	CONFIGURATION
HMS	1 – 2500 MHz	SMT Leadless
HMC	10 – 3000 MHz	Miniature PCB / SMA

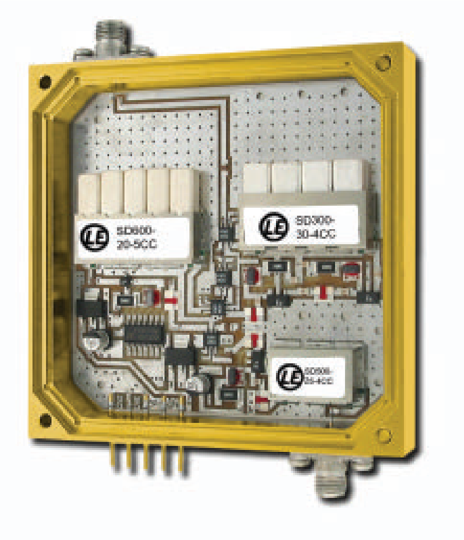
LOWPASS	CUT OFF FREQUENCY RANGE	CONFIGURATION
LMS	0.5 – 5000 MHz	SMT Leadless
LMC	0.5 – 6000 MHz	Miniature PCB / SMA

Please call Lark Engineering if your requirements fall outside of our standard range.

Multi-Function Assemblies

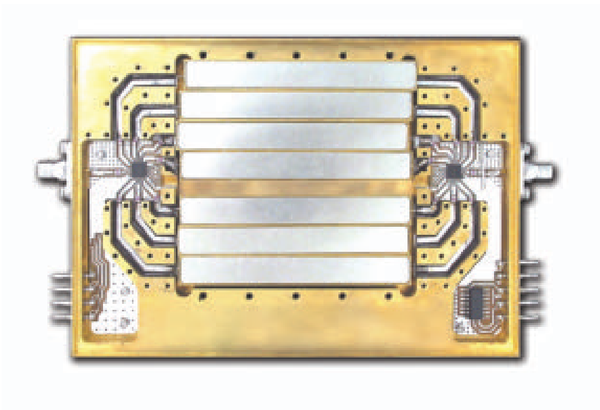
Lark's new Switch Filter Systems are designed with a wide array of Switch Filter Banks and low noise amplifiers. They are available in Ceramic and Lumped Element configurations, low profile connectorized packages and a wide frequency range. Switch Filters are ideally suited for receiver applications and assisting in overall system performance.

Switch Filter Amplifier- SFA series



SPECIFICATION	STANDARD
Frequency	100 to 8000 MHz
3dB Bandwidth	1 to 40%
Nominal Impedance	50 Ω
Gain	10 to 40 dB
Return Loss	18 dB typical 14 dB min.
Noise Figure	1.5-5.0 dB typical
Number of channels	2, 3, 4, 5, and 6
Switching Speed	300 μS max.
Bias	+ 5, +10, +15 V DC
Shock	5 G's
Gross Leak	Mil STD 202 Method 112 Condition D
Fine Leak 10^ -7	Mil STD 202 Method 112 Test Condition C
Vibration	5 G's
Humidity	95%
Altitude	+/- 50,000 ft
Package	SMA, feed thru pins, or SMT

Switch Filter Bank- SFB series



SPECIFICATION	STANDARD
Frequency	DC to 18 GHz
3dB Bandwidth	1 to 40%
Nominal Impedance	50 Ω
Max Insertion Loss	2-10 dB
Return Loss	18 dB typical 14 dB min.
Number of channels	2 to 10
Input Power	+27 dBm
Switching Speed	50 ns to 1 μS
Bias	+5, -5, -12, -15, +10, +15 V DC
Control	TTL
Shock	5 G's
Gross Leak	Mil STD 202 Method 112 Condition D
Fine Leak 10^ -7	Mil STD 202 Method 112 Test Condition C
Vibration	5 G's
Humidity	95%
Altitude	+/- 50,000 ft
Package	SMA, feed thru pins, or SMT

Contact Lark Engineering with your specific needs.

New Products

Switch Filter Systems

PRODUCT SPECIFICATIONS:

Frequency Range	DC to 18 GHz
Number of channels	2 to 10
Insertion Loss	2 to 10 typical
Isolation	40 to 75 dB typical
VSWR	1.5:1 to 2.0:1 typical
Switching Speed	50 ns typical to 1 µs
Input Power	+27 dBm CW
Control	TTL, BCD
Power Supply	+5, -5, -12, -15 V DC
Connectors	Connectorized, Pin or Leadless SMT

* Low Profile Models Available

LOW PROFILE, LEADLESS CAVITY FILTERS

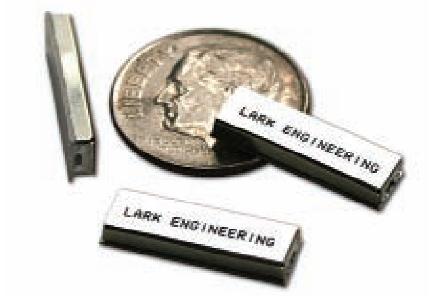
0.22” Height

PRODUCT SPECIFICATIONS:

- Frequency Range: Up to 20 GHz
- Bandwidths: Up to 30%
- Low Insertion Loss
- Meets Mil-Std-202
- Leadless SMT Package
- Available on Tape & Reel
- Custom Designed to your Specifications

ULTRA-THIN FILTERS

Less than 0.09” High



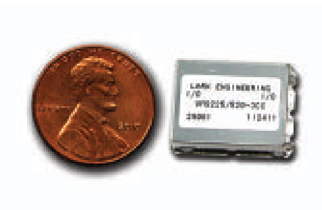
When size is critical, Lark is offering a full line of Ultra-Thin filters for the Commercial and Military markets. Lark’s new Ultra-Thin package offers superior performance in less than **0.09”** high package. The Ultra-Thin filter series offers low insertion loss and ultimate rejection levels of 60 dB while maintaining better than 1.5:1 VSWR. These units are lightweight and ruggedized for today’s military applications.

PRODUCT SPECIFICATIONS:

- Available in Bandpass, Highpass, Lowpass & Band Reject
- Frequency Range: 20 MHz to 5.0 GHz
- Passbands: Up to 60%
- VSWR: 1.5:1 typical
- Ultimate Rejection: 60 dB
- Meets Mil-Std-202 conditions
- Temperature Range: -55° C to +85° C

Digitally Tunable Filters

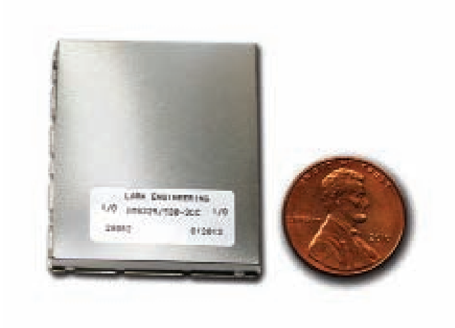
MINIATURE VOLTAGE CONTROLLED FILTERS



PRODUCT SPECIFICATIONS:

- Frequency Coverage: 10 MHz to 1 GHz
- Percent Bandwidth: 5 to 20%
- 3 dB/30 dB Shape Factor: 4.5:1
- Input/Output Impedance: 50 Ohms
- Inband RF Power Handling: Up to 1 Watt
- Inband Third Order Intercept: 10 dBm
- Tuning Control: Voltage Controlled
- Tuning Speed: 450 µS
- DC Power: 0 to 15v @ 1mA
- Operating Temperature Range: -40 to +85 °C
- Size (L x W x H inches): 1.00 x .75 x 0.35 max.

COMPACT DIGITAL CONTROL FILTERS



PRODUCT SPECIFICATIONS:

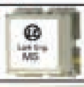
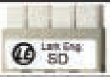
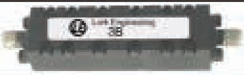
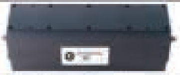
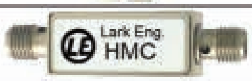
- Frequency Coverage: 10 MHz to 1 GHz
- Percent Bandwidth: 5 to 20%
- 3 dB/30 dB Shape Factor: 4.5:1
- Input/Output Impedance: 50 Ohms
- Inband RF Power Handling: Up to 1 Watt
- Inband Third Order Intercept: 10 dBm
- Tuning Control: 8 bit parallel TTL
- Tuning Speed: 450 µS
- DC Power: 15 VDC @ 50 mA
- Operating Temperature Range: -40 to +85 °C
- Size (L x W x H inches): 1.25 x 1.5 x .35 max.

STANDARD DIGITAL CONTROL FILTERS

PRODUCT SPECIFICATIONS:

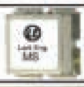
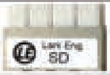
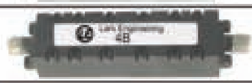
- Frequency Coverage: 1.5 MHz to 1 GHz
- Percent Bandwidth: 4 to 20%
- 3 dB/30 dB Shape Factor: 6.8:1
- Input/Output Impedance: 50 Ohms
- Inband RF Power Handling: Up to 1 Watt
- Inband Third Order Intercept: 30 dBm
- Tuning Control: 8 bit parallel
- Tuning Speed: 10 µS to 50 µS
- DC Power: (+5) VDC @ 10 to 250 mA
  (+) 50 VDC @ 1mA
- Operating Temperature Range: -40 to +85 °C
- Size (L x W x H inches): 2.5 x 2 x .75 max.

ELECTRICAL SPECIFICATIONS
1 MHz to 32 GHz

Series	Configuration	Center Frequency (Fc)	Number of sections	Nominal Impedance	Max. VSWR	Max. Input Power (avg.)	Max. Input Power (peak)
BANDPASS FILTERS							
MS 	Surface Mount	1 to 5000 MHz	3 to 7	50 Ω	1.5/1	2 W	20 W
		1 to 6500 MHz	2 to 10	50 to 300 Ω	1.3/1	10 W	50 W
MC 	Miniature	1 to 5000 MHz	3 to 7	50Ω	1.5/1	2 W	20 W
		0.1 to 6000MHz	2 to 10	50 to 300 Ω	1.3/1	20 W	100 W
SD 	Ceramic	250 to 5000 MHz	2 to 7	50Ω	2/1	1 W	2 W
		200 to 6000 MHz	2 to 10	50 to 75 Ω	1.5/1	10 W	50 W
SDP 	High Power	400 to 2000 MHz	2 to 4	50Ω	1.5/1	50 W	250 W
	Surface Mount	350 to 2250 MHz	2 to 5	50 to 75 Ω	1.3/1	50 W	250 W
SDN 	Band Reject	300 to 2500 MHz	3 to 6	50 Ω	2/1	1 W	2 W
	Surface Mount	250 to 3500 MHz	2 to 8	50 to 75 Ω	1.5/1	2 W	10 W
3B 	Combline	1000 to 26000 MHz	3 to 10	50 Ω	1.5/1	Up to 20 W	Up to 200 W
		1000 to 32000 MHz	2 to 14	50 Ω	1.3/1	Call Lark	Call Lark
4B 	Miniature	1000 to 26000 MHz	3 to 8	50 Ω	1.5/1	Up to 10 W	Up to 100 W
	Combline	1000 to 32000 MHz	2 to 14	50 Ω	1.3/1	Call Lark	Call Lark
SMC 	Surface Mount	5000 to 15000 MHz	2 to 6	50 Ω	1.5/1	Call Lark	Call Lark
	Combline						
2C 	Hi-Q	50 to 400 MHz	3 to 6	50 Ω	1.5/1	Up to 8 W	Up to 37.5 W
	Cavity	50 to 500 MHz	2 to 7	50 to 100 Ω	1.3/1	Call Lark	Call Lark
3C 	Hi-Q	400 to 2000 MHz	3 to 6	50 Ω	1.5/1	Up to 30 W	Up to 30 W
	Cavity	400 to 2500 MHz	2 to 7	50 Ω	1.3/1	Call Lark	Call Lark
4C 	Hi-Q	800 to 2500 MHz	3 to 6	50 Ω	1.5/1	Up to 50 W	Up to 200 W
	Cavity	750 to 2500 MHz	2 to 7	50 Ω	1.3/1	Call Lark	Call Lark
5C 	Hi-Q	1000 to 3000 MHz	3 to 6	50 Ω	1.5/1	Up to 7.5 W	Up to 30 W
	Cavity	800 to 4000 MHz	2 to 7	50 Ω	1.3/1	Call Lark	Call Lark
6C 	Hi-Q	2000 to 7500 MHz	3 to 6	50 Ω	1.5/1	Up to 7.5 W	Up to 30 W
	Cavity	2000 to 9000 MHz	2 to 7	50 Ω	1.3/1	Call Lark	Call Lark
LOWPASS FILTERS		CUT OFF FREQUENCY					
LMS 	Surface Mount	1 to 3500 MHz	3 to 7	50 Ω	1.5/1	2 W	20 W
		0.5 to 5000 MHz	2 to 10	50 to 300 Ω	1.3/1	10 W	50 W
LMC 	Miniature	1 to 3500 MHz	3 to 6	50 Ω	1.5/1	2 W	20 W
		0.5 to 6000 MHz	2 to 10	50 to 300 Ω	1.3/1	20 W	100 W
HIGHPASS FILTERS		CUT OFF FREQUENCY					
HMS 	Surface Mount	10 to 1500 MHz	3 to 6	50 Ω	1.5/1	2 W	20 W
		1 to 2500 MHz	2 to 10	50 to 300 Ω	1.3/1	10 W	50 W
HMC 	Miniature	10 to 2000 MHz	3 to 6	50 Ω	1.5/1	2 W	20 W
		1 to 3000 MHz	2 to 10	50 to 100 Ω	1.3/1	20 W	100W

ENVIRONMENTAL SPECIFICATIONS
ISO 9001 AND ISO 14001 Certified

All packages can be designed to meet full Military environmental requirements. **BANDPASS FILTERS**

Shock	Vibration	Humidity (% Relative)	Temp. Range (Operating)	Temp. Range (Non-Operating)			Series
20 G's	10 G's	95%	-40°C to + 85°C	-65°C to + 125°C	Standard		MS
75 G's	30 G's	95%	-55°C to + 125°C	-65°C to + 150°C	Special		
20 G's	10 G's	95%	-40°C to + 85°C	-65°C to + 125°C	Standard		MC
75 G's	30 G's	100%	-55°C to + 125°C	-65°C to + 150°C	Special		
20 G's	10 G's	95%	-40°C to + 85°C	-65°C to + 125°C	Standard		SD
75 G's	30 G's	100%	-55°C to + 125°C	-65°C to + 150°C	Special		
15 G's	5 G's	90%	-30°C to + 85°C	-54°C to + 100°C	Standard		SDP
75 G's	30 G's	100%	-54°C to + 100°C	-62°C to + 150°C	Special		
15 G's	5 G's	90%	-30°C to + 85°C	-54°C to + 100°C	Standard		SDN
75 G's	30 G's	100%	-54°C to + 100°C	-62°C to + 150°C	Special		
25 G's	10 G's	95%	-40°C to + 85°C	-65°C to + 125°C	Standard		3B
50 G's	20 G's	100%	-55°C to + 125°C	-65°C to + 150°C	Special		
25 G's	10 G's	95%	-40°C to + 85°C	-65°C to + 125°C	Standard		4B
50 G's	20 G's	100%	-55°C to + 125°C	-65°C to + 150°C	Special		
Call Lark	Call Lark	95%	-40°C to + 85°C	-54°C to + 100°C	Standard		SMC
20 G's	10 G's	95%	-25°C to + 85°C	-54°C to + 125°C	Standard		2C
20 G's	15 G's	100%	-54°C to + 85°C	-54°C to + 125°C	Special		
20 G's	10 G's	95%	-25°C to + 85°C	-54°C to + 125°C	Standard		3C
20 G's	15 G's	100%	-54°C to + 85°C	-62°C to + 125°C	Special		
20 G's	10 G's	95%	-25°C to + 85°C	-54°C to + 125°C	Standard		4C
25 G's	20 G's	100%	-54°C to + 85°C	-54°C to + 125°C	Special		
20 G's	10 G's	95%	-25°C to + 85°C	-54°C to + 125°C	Standard		5C
25 G's	20 G's	100%	-54°C to + 85°C	-54°C to + 125°C	Special		
20 G's	10 G's	95%	-25°C to + 85°C	-54°C to + 125°C	Standard		6C
25 G's	20 G's	100%	-25°C to + 85°C	-54°C to + 125°C	Special		

All packages can be designed to meet full Military environmental requirements. **LOWPASS FILTERS**

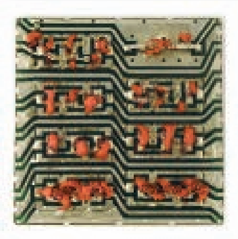
Shock	Vibration	Humidity (% Relative)	Temp. Range (Operating)	Temp. Range (Non-Operating)			Series
20 G's	10 G's	95%	-55°C to + 85°C	-65°C to + 125°C	Standard		LMS
50 G's	15 G's	100%	-55°C to + 100°C	-65°C to + 125°C	Special		
20 G's	10 G's	95%	-55°C to + 85°C	-65°C to + 125°C	Standard		LMC
50 G's	15 G's	100%	-55°C to + 100°C	-65°C to + 125°C	Special		

All packages can be designed to meet full Military environmental requirements. **HIGHPASS FILTERS**

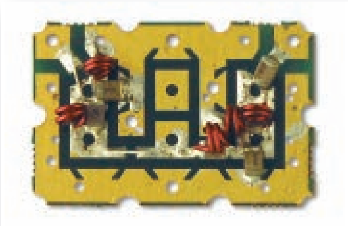
Shock	Vibration	Humidity (% Relative)	Temp. Range (Operating)	Temp. Range (Non-Operating)			Series
20 G's	10 G's	95%	-55°C to + 85°C	-65°C to + 125°C	Standard		HMS
50 G's	15 G's	100%	-55°C to + 100°C	-65°C to + 125°C	Special		
20 G's	10 G's	95%	-55°C to + 85°C	-65°C to + 125°C	Standard		HMC
50 G's	15 G's	100%	-55°C to + 100°C	-65°C to + 125°C	Special		

LARK ENGINEERING CAPABILITES

Satcom Diplexer
In response to the current market demand for a lighter filter with a reduced form factor while maintaining competitive electrical performance, Lark offers its compact satcom diplexers. Our new design saves both space and weight for all systems working in the Satcom bands.
- Standard Diplexer Dimensions: 21.00” L x 6.50” W x 5.00” H
- Compact Diplexer Dimensions: 6.25” L x 3.00” W x 2.00” H



Ceramic Diplexers
Lark Engineering’s family of Ceramic Diplexers is based on our stand-alone ceramic filter series. The ceramic diplexer series uses a PCB / PWB board carrier with outputs in the corners and an axial port along the opposite side to provide the best channel-to-channel isolation. Through the addition of input matching circuitry, the ceramic diplexer is able to provide the best common junction match. Our design algorithms are capable of matching any two non-contiguous passbands using various filter configurations.

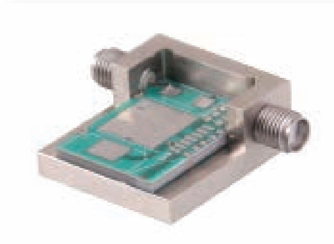


Triplexers and Multiplexers
Along with the Diplexer series of filters, Lark also offers Triplexers and Multiplexers. By creating a basic network of three or more bandpass series filters, a Triplexer or Multiplexer is able to separate the passband frequencies and apply the signal to isolated terminals. The passband of the individual network may be contiguous or separated by overlapping stopbands.

Ultra Compact Ceramic Filters
When board space is a premium and getting the best performance in a very small footprint is a must, Lark can offer ultra compact ceramic filters with resonator sizes as small as 1.5mm. This filter provides the performance you need from a standard ceramic filter but in a size equal to or smaller than 8x8mm depending on the number of resonators.

Elliptic Function Filters
Elliptic designs are available for very sharp rejection responses. This type of response can be used on Lump Element, Ceramic and Cavity filter designs.

Cross Coupled Cavities
To improve rejection in your filter without increasing the size, Lark offers a cross coupled cavity filter design. Using a semi-elliptical arrangement, resonators are cross-coupled to approach zeros in transmission. The zeros in transmission can be placed in the upper or lower side of the rejection skirt depending on your needs.



True Tune™ Test Fixtures
With designs becoming more and more complex it is essential that the performance of the filters be similar on a test fixture as on your board. Lark Engineering will take your PCB / PWB and create a test fixture to fine tune the filters. This will significantly reduce the need for final tuning in production by matching the impedance and capacitance associated with your board. Lark offers this service to its customers to facilitate their time to market and success.

Legacy Filters
In addition to our surface mount and ceramic bandpass filters, Lark Engineering continues to offer the 2B, TO-8 and Tubular filter series. The 2B series is an interdigital configuration ranging in center frequency from 1,000 to 12,000MHz. The TO-8 series is offered in Lowpass, Highpass and Bandpass, and range in center frequency from 10 to 5000 MHz. The Tubular series offers Bandpass, Lowpass and Highpass filters ranging in center frequency of 60 to 8000 MHz.

LARK ENGINEERING FILTER DESIGN TOOL

Visit our website FILTER DESIGN TOOL at www.larkengineering.com.

CLICK ON THE FILTER DESIGN TOOL ICON.

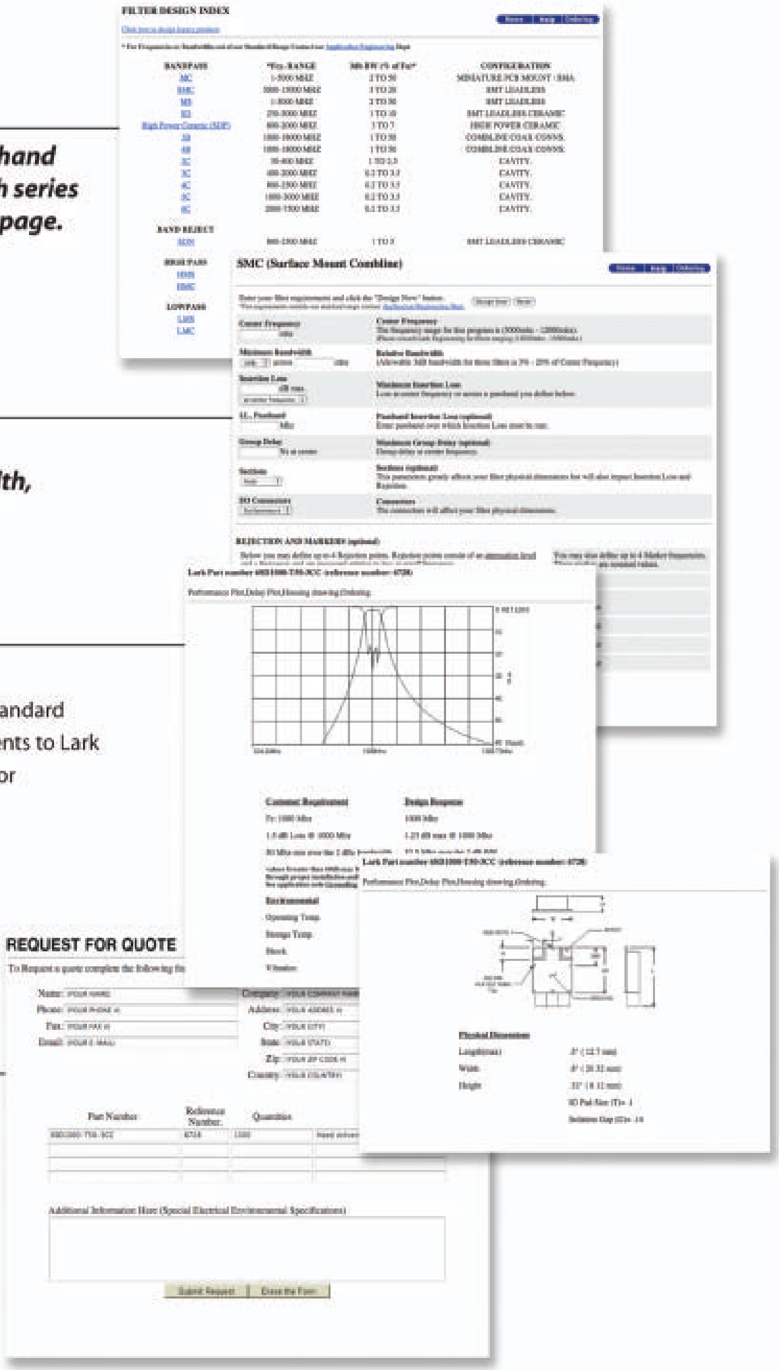
Just follow the simple steps to determine the optimal filter Lark Engineering can offer for your requirements. At any time you can click on the HELP button and use the FILTER DESIGN DEMO for directions and examples.

1 ***Select a FILTER SERIES in the left hand column. If you are not sure which series to use, check out our Filter Index page.***

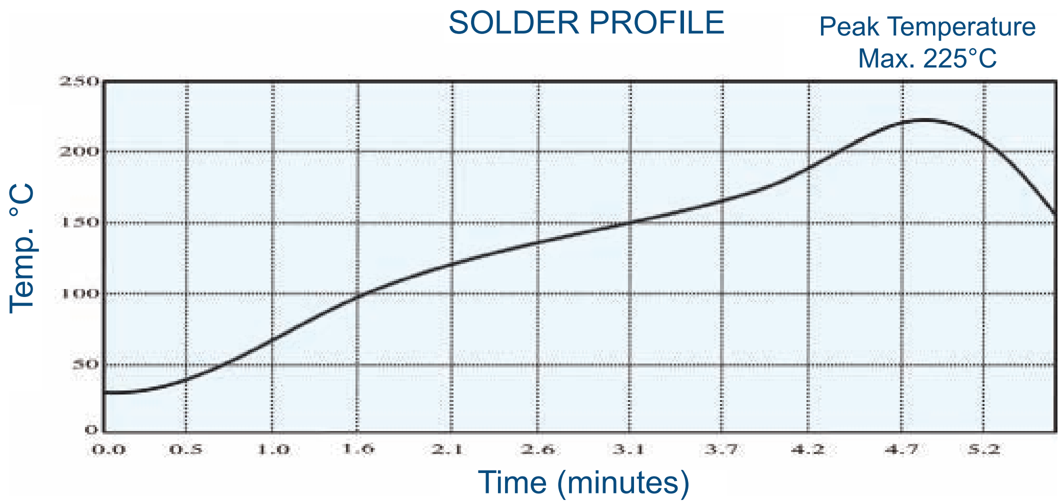
2 ***Enter your filter requirements... Your desired frequency, bandwidth, insertion loss, etc.***

3 ***Click the "Design Now" button.***
If your filter design is outside of Lark's standard range, forward your captured requirements to Lark via e-mail: Sales@larkengineering.com, or fax to: 949-240-7910.

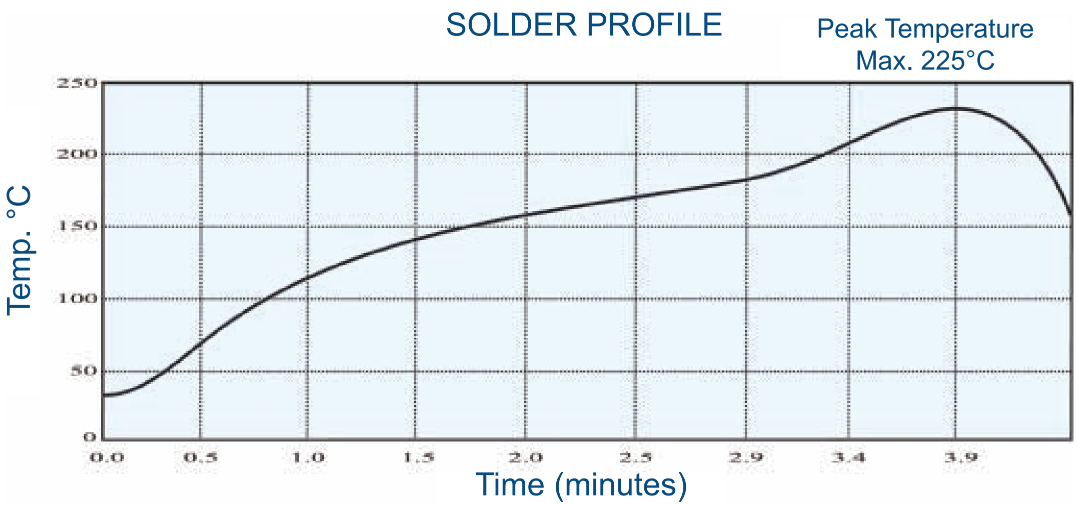
For your convenience a Request for Quote form is available on our website.



Recommended Solder Conditions for
Non RoHS compliant (Leaded) Surface Mount Ceramic Filters: SD, MXD & SMC Series



Recommended Solder Conditions for
Non RoHS compliant (Leaded) Surface Mount Filters: MS Series



If acqueous cleaning is used for flux removal, bake parts at least 1 minute at 80°C maximum after water rinse.

- Reflow must be done with alloys SN62 or SN63

- Registration of solder paste should cover a minimum of 90% of in/out pads, and the thickness should be .006” minimum to .010” maximum.

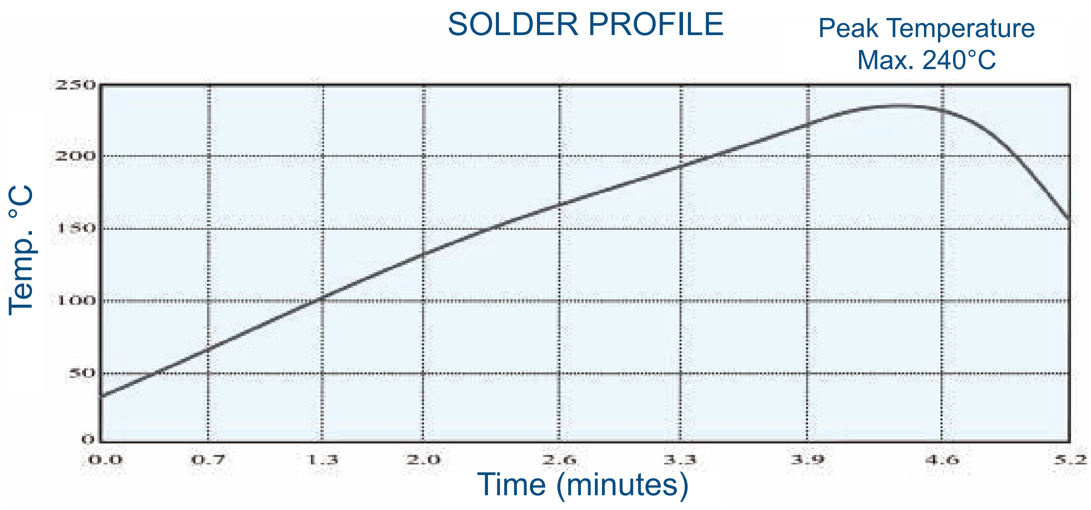
- Pre-tinned with an SN90/10 alloy.

- No solderability problems should occur if prior recommendations are followed.

NOTE: Must apply solder paste in conformance with layout printed circuit design (registration) as shown in the Lark catalog. The complete Lark Engineering catalog can be downloaded by visiting our website at www.larkengineering.com

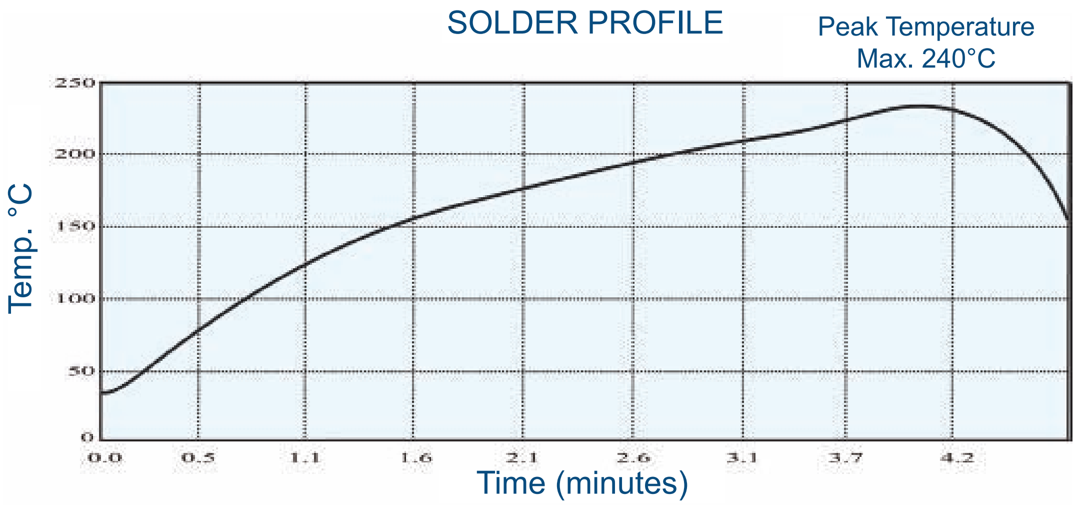
Recommended Solder Conditions for

RoHS compliant (Lead Free) Surface Mount Ceramic Filters:
SD, MXD & SMC Series



Recommended Solder Conditions for

RoHS compliant (Lead Free) Surface Mount Filters:
MS Series



If acqueous cleaning is used for flux removal, bake parts at least 1 minute at 80°C maximum after water rinse.

- Lark recomends using SAC305 (Tin / Silver / Copper) or Sn96/Ag4 (Tin / Silver) solder paste.
- Alternative alloys may be used provided the liquidous temperature does not exceed 221°C
- Registration of solder paste should cover a minimum of 90% of in/out pads and the thickness should be .006” minimum to .010” maximum.
- No solderability problems should occur if prior recommendations are followed.

NOTE: Must apply solder paste in conformance with layout printed circuit design (registration) as shown in the Lark catalog. The complete Lark Engineering catalog can be downloaded by visiting our website at www.larkengineering.com

Rest at Ease with our Customer Friendly Website and Ordering Process.

Lark Engineering Co.™

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