Vol. 51 • No. 1

January 2008

Microwave Journal

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Radar/Antennas

Array Radars: Potential and Limitations

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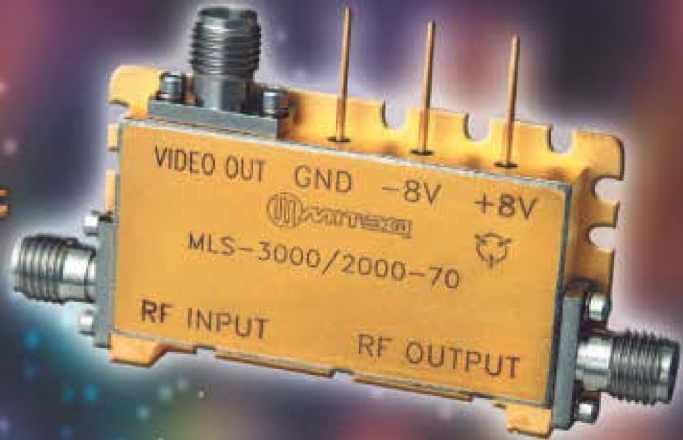

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MLS-2000/1000-70	1500 to 2500	-67 to +3	-70	±1.5	15	30	40
MLS-3000/2000-70	2000 to 4000	-70 to 0	-72	±2.0	10	25	35
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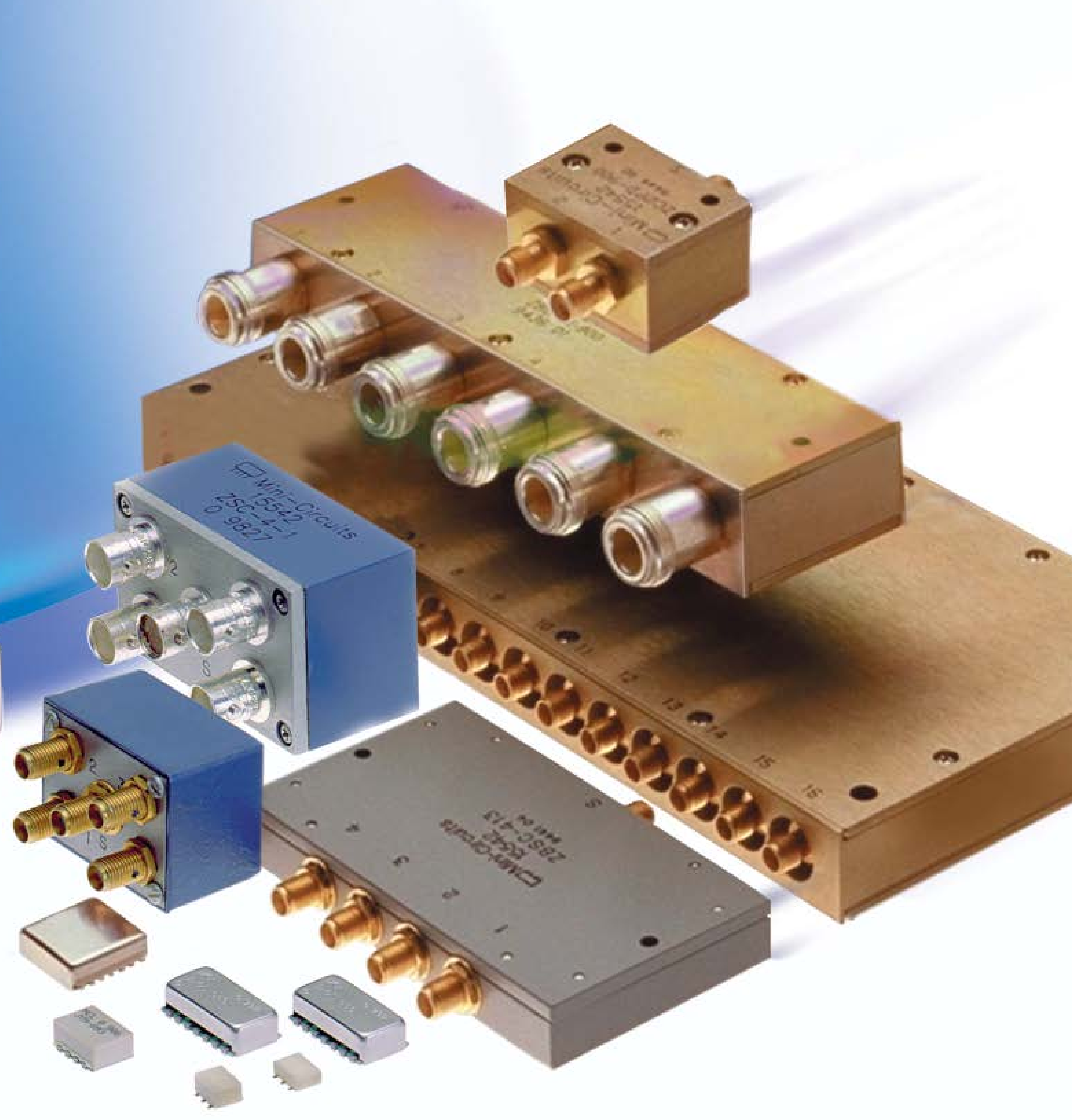
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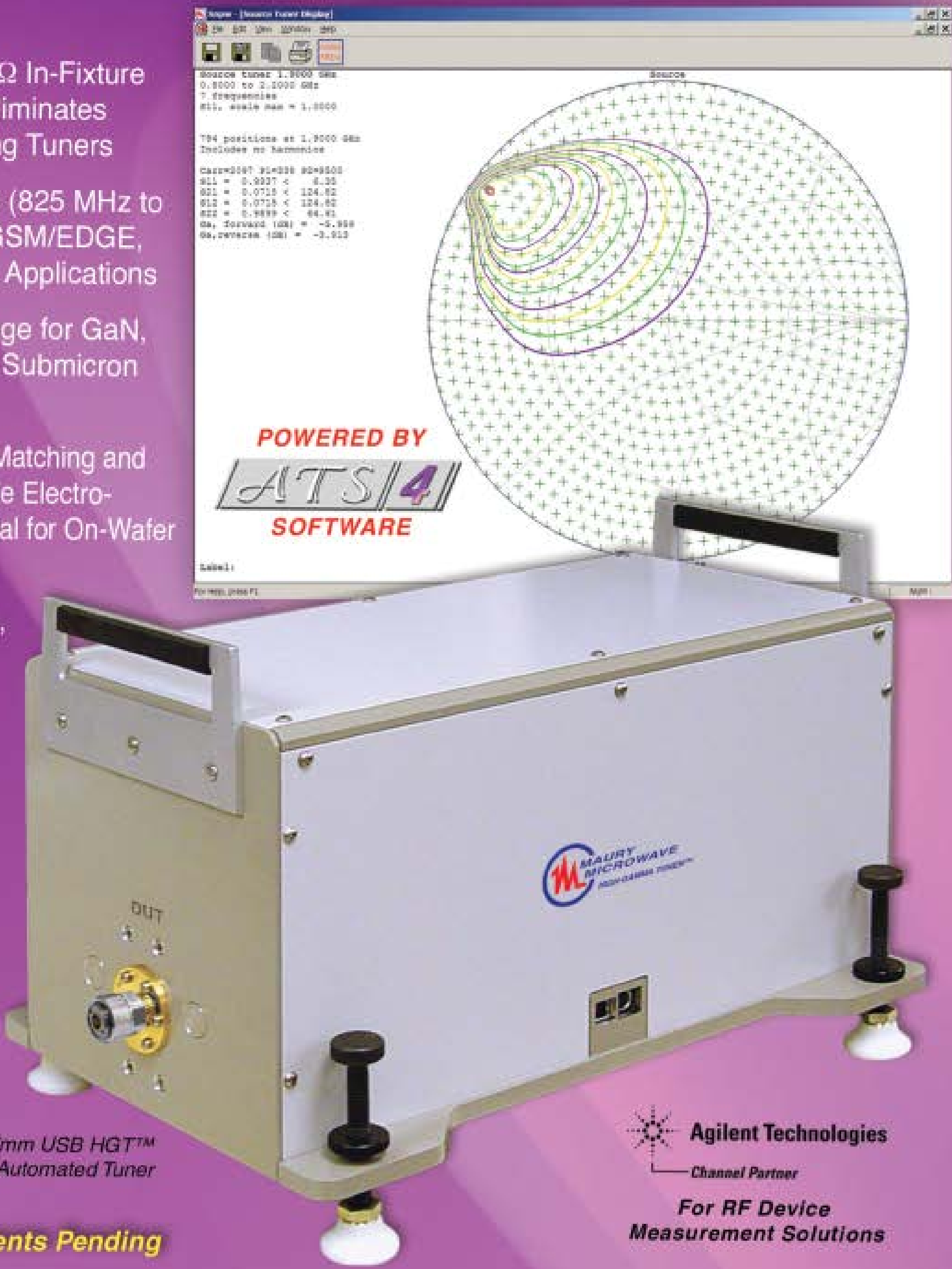

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FEATURES

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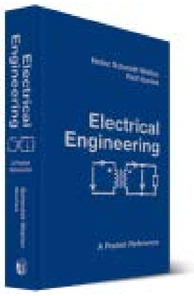
Expert Advice

New online feature: Each month, *Microwave Journal* asks a noted industry expert to provide commentary related to the issue's technical theme. Our invited expert's editorial is a starting point for an interactive dialog among our readers. Readers may post responses as part of an ongoing technical discussion. Be part of the conversation—read and share your comments, experiences or opinions at www.mwjournal/experts.



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January: Dr. Vince Rodriguez, Senior Principal Antenna Design Engineer with the Field Generation Group of ETS-Lindgren, shares some thoughts on the challenges of accurately testing today's high-frequency antenna patterns.

Executive Interview

In this month's executive interview, *Microwave Journal* talks with Brian Dupell, President of **DLI**, about today's spectrum management challenges, the radar market and the role of High-Q ceramic-based RF/mW components in achieving the performance required by today's military and commercial applications.

CELEBRATING 50 YEARS

In July of 1958, a group of industry pioneers led by William Bazzy and including Ted Saad, Seymour Cohn, Henry Jasik, Ben Lax, Marshall Pease, Tore Anderson and Gersh Wheeler launched *Microwave Journal*. This year, we'll celebrate our 50th year milestone with a number of monthly print and online features and a commemorative 50th anniversary July issue which will celebrate the people, the companies and the events that have helped to shape the RF/microwave industry during the past half century.

This issue debuts our monthly "Then and Now" cover story, which features a reprinted article from the early years of MWJ that relates to the current month's editorial theme, followed by an invited article that provides an update to the current state-of-the-art for each technology or product focus. This month's reprinted article was written by J.L. Allen of MIT's Lincoln Laboratory and was first published in the May 1962 issue. The title of the article is "Array Radars: A Survey of Their Potential and Their Limitations." Renowned radar expert and IEEE Life Fellow Eli Brookner authors our guest editorial. The title of his article is "Phased-array Radars: Past, Astounding Breakthroughs and Future Trends." I hope that you find this retrospective to be informative and enjoyable reading.

The MWJ web site (mwjournal.com) will showcase many new features and improvements this year. We'll be sure to keep you informed as these are implemented. This month debuts the new "Expert Advice" feature, which represents the next generation of the popular "Ask Harlan" column. In this online resource, MWJ asks a noted industry expert to provide commentary related to the monthly editorial theme. Reader responses will be posted as part of an online dialog for all to share. The first five people to post a qualified response each month will win a copy of the new Artech House book titled *Electrical Engineering: A Pocket Reference*. This month's expert is Dr. Vince Rodriguez, Senior Principle Design Engineer with the Field Generation Group of ETS-Lindgren. Check it out on our web site and post your comment soon. I think that you'll really like this feature (and the reference guide).

In February, watch for our "Company Profile" series, highlighting company spotlights from the early years, accompanied by updated profiles of those companies today. I found it quite interesting how many of these companies have evolved over the decades and several have spawned an entire corporate family tree.

I'm excited about the year ahead and I'm proud to be associated with a publication that has had such tremendous staying power, especially in these times of constant change. Sincere thanks go out to our loyal readers, advertisers and editorial contributors for allowing us to serve this industry for so long. I would be remiss if I did not also thank the MWJ staff, who work hard to keep up with these changes and who consistently deliver quality products in print and online.

Wishing all of our readers a happy, healthy and prosperous New Year.

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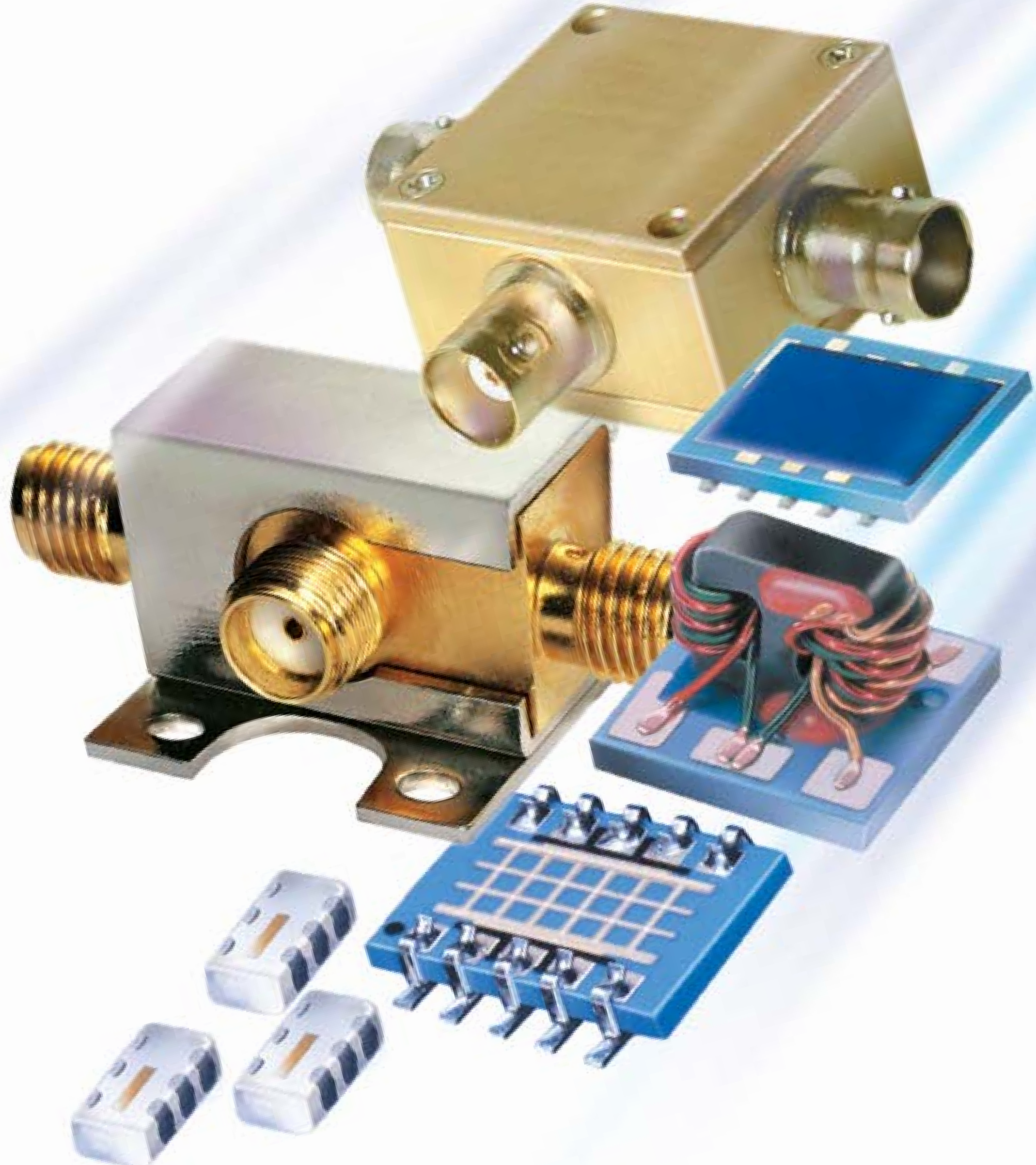

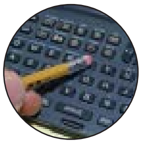

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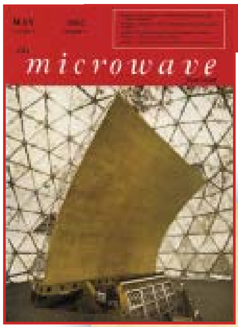

ARRAY RADARS

A Survey Of Their Potential And Their Limitations

J. L. ALLEN
LINCOLN LABORATORY*
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Lexington • Massachusetts

Editor's Note — The array type of antenna has come from a little used concept in World War II to an item of major importance today. Fixed beam arrays with electronic lobing are being used to replace fire control dish antennas, multiple beam arrays are being used for airport surveillance, large electronic scanning arrays are being used for target detection and tracking. The Microwave Journal is pleased to announce a series of articles on Phased Arrays and Electronic Scanning. Covered in the series will be electronic lobing, simultaneous scanning, tubes for distributed amplifier arrays, and other subjects. The following article by J. L. Allen initiates the series.

I. Introduction

The present traffic of satellites, space probes and missiles has placed increasing demands upon radar performance. More radiated power, larger precision antennas, greater receiver sensitivity and improved extraction of information are required. Thus, radars have grown from the "heavy" radars of World War II, of which Figure 1 is typical, to "space age" installations such as that of Figure 2 in which the surveillance radar antenna area is greater than that of a football field.

As the demands continue to grow, the radar designer is forced into ever more conflicting requirements, such as the simultaneous need for larger, more precise antennas and for faster scanning until he is led to consider approaches so radical as to have been considered impractical in the light of previous demands. One approach, the first significant realization of which predates World War II (10**), is the use of the array antenna configuration in which a large number of antennas are used, interconnectetd to radiate coherently. By incorporating phase shifters with each antenna, a beam can be formed and "steered" over quite wide angles without antenna motion; and by the use of electronically variable phase shifters, the beam can be moved in microsecond times. Thus, we have come to another "new look" in radar, the "array radar," of which Figure 3 is representative.

The purpose of this paper is to explore in a qualitative way the potentials and limitations of array radars, with emphasis on ground-based, long range radar applications.

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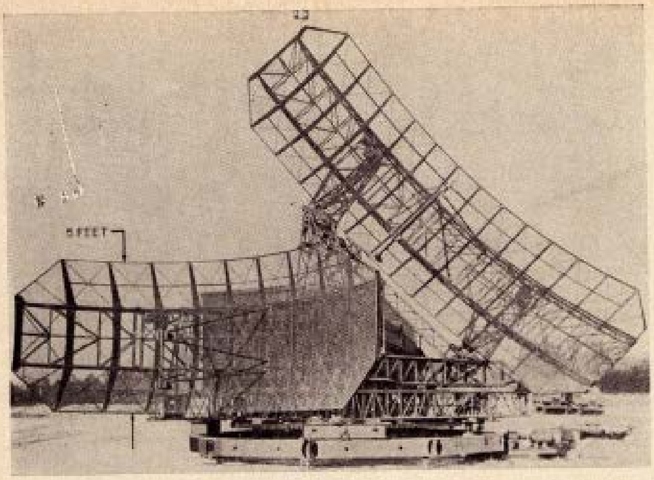


Figure 1 — World War II "heavy" radar.

To lay the groundwork for such an exploration, we will first briefly review some fundamental array types and limitations. The parameters of a radar that are most basic to its ability to successfully perform the three radar functions of detection, resolution and measurement will then be reviewed. The capacity of array configurations to perform these functions will be compared with the capacity of more conventional radars, and the resultant complexities and costs pointed out. Areas of research which offer promise of reduction of these costs will be indicated.

II. Some Background Data

While we will not delve into the technical details of array antennas*, it will be useful as grounding for later discussion to briefly point out the size (number of antennas) of arrays likely in radar applications and some fundamental array configurations. It will be seen that while the performance objective largely determines the number of elements, arrays still come in different degrees of complexity, capability and, axiomatically, cost.

**Some of the references contain detailed discussions of theory as well as further references; see particularly Refs. 2, 3, 27, 28, 30.*

A. The Number of Antennas Required for Array Radars

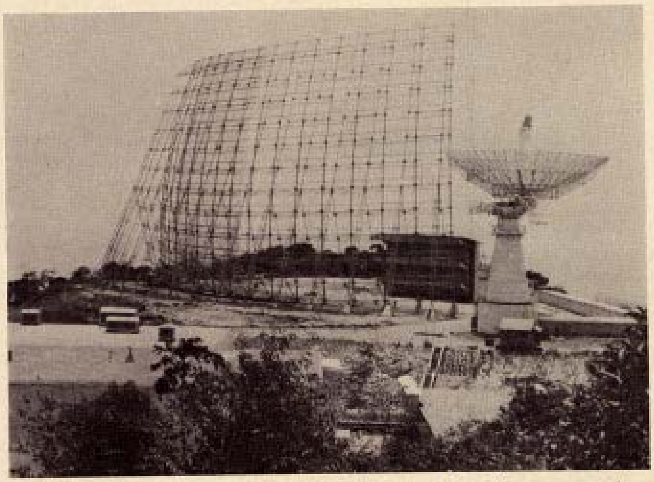
The complexity of an array is certainly proportional to the number of individual antennas (elements).

As a crude, but useful guide, a flat (planar) array, with half-power beamwidths θ and ϕ degrees in elevation and azimuth planes, requires a number of elements, N, of the order of

$$N \approx \frac{10^4}{\theta \phi}$$

indicating that, for example, a pencil beam 1° x 1° requires roughly 10,000 antenna elements. Further, the usable angle of scan of a single planar array is limited by the decrease in the projected size of the antenna at wide angles. As wider angles of scan are attempted, the number of elements required to realize a desired system sensitivity increases so rapidly that it would be economically more practical to

Figure 2 — Missile surveillance and tracking radars.



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APA3438-35	3.4 to 3.6	30	3.5	0.5	35	45	2.8 A
APA3438-38	3.4 to 3.6	30	3.5	0.5	38	48	3.4 A
APA3438-41	3.4 to 3.6	30	3.5	0.5	41	51	5.5 A
APA3642-39	3.6 to 4.2	40	4.0	1.0	39	49	3.3 A
APA4450-40	4.4 to 5.0	40	4.0	1.0	40	50	5.5 A
APA4450-42	4.4 to 5.0	40	4.0	1.0	42	52	3.3 A
APA4450-44	4.4 to 5.0	40	4.0	1.0	44	54	9.5 A
APA5964-36	5.9 to 6.4	40	4.5	0.5	36	46	2.6 A
APA5964-42	5.9 to 6.4	40	4.5	1.0	42	52	5.3 A
APA5964-44	5.9 to 6.4	40	4.5	1.0	44	54	9.5 A
APA5864-46	5.8 to 6.4	40	4.5	1.0	46	56	11.0 A
APA6472-36	6.4 to 7.2	40	4.5	0.5	36	46	2.6 A
APA6472-42	6.4 to 7.2	40	4.5	1.0	42	52	5.9 A
APA7785-39	7.7 to 8.5	40	4.5	1.0	39	49	3.6 A
APA1112-36	10.7 to 11.7	40	4.5	0.5	36	46	2.6 A
APA1112-42	10.7 to 11.7	40	4.5	1.0	42	52	5.9 A
APA1414-37	14.0 to 14.5	40	4.5	0.5	37	47	2.6 A
APA1414-40	14.0 to 14.5	40	4.5	0.5	37	47	2.6 A
APA1414-43	14.0 to 14.5	40	4.5	0.5	37	47	2.6 A
APA3031-36	30.0 to 31.5	27	6.0	1.0	36	43	5.6 A

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build more than one array with faces pointed at different angles, with each array having less stringent scanning requirements. For arrays on a flat surface, a scanning cone of 90° to 100° central angle is achievable. Thus, to scan a hemisphere, as most present aircraft surveillance radars do, would require at least four arrays.

How about arrays on cylinders or spheres? Investigation of these configurations will show that the limitations on the percentage of the surface that can be used to produce a beam at one instant are such that about the same number of elements are required for a given surveillance volume, regardless of the geometry.

Thus, in the following discussion, the reader should bear in mind that for two-dimensional arrays, the number of elements involved is likely to be of the order of thousands and several array faces may be required to survey the volume.

B. *Some Typical Array Configurations**

Figures 4 and 5 distinguish between two basic classes of arrays (using linear arrays as examples, although most of the techniques can be extended to other surfaces).

The configurations of Figure 4 represent fundamental versions of what might be termed "steerable" arrays, in that they produce a single beam at the terminal point which can be scanned by varying the element phasing. Shown in the Figure are the simplest forms of the basic techniques: frequency variation, the use of variable phase shifters and the use of variable delays, roughly in order of both increasing complexity and increasing capability for handling broadband signals. Many embellishments of these basic techniques exist[27,28] but will not be discussed here.

Figure 5 shows three fundamental configurations of "multi-beam" arrays[5,6,27]. These devices form many simultaneous beams fixed in spatial position. Each beam has the full gain normally associated with an array of the size used, subject to some limitations on beam shapes and closeness of beam spacing (cross-over levels)[1].

Since the multi-beam feeds are fabricated entirely of non-variable, passive circuitry, they can be made more reliable, cheaper and more reproducible than steerable arrays. On the other hand, as a result of the fixed nature of the beams, angular information is inherently somewhat** less accurate on the average than from a steerable beam array. This decreased accuracy arises from the fact that angular measurement accuracy varies, depending upon the target's location in the beam. With steerable arrays, this position may be optimized for each target; with the basic multi-beam arrays, one must settle for whatever comes.

For two-dimensional scanning, one can use "arrays of arrays," as indicated for the multi-beam type array in Figure 6. Further, it is often profitable to employ "hybrid" systems in which one technique is used for combining rows of elements and another for columns in a planar array. Thus, for example, one might use frequency variation to scan along the rows with each row schematically resembling Figure 4a, with each row acting as an "element" of a feed of the type of Figure 4b, using variable phase shifters. Another useful combination might be to use multi-beam feeds in rows with phased feeds in columns to implement a steered stack of beams, and so forth. Separate transmitting and receiving arrays using different techniques may also be advantageous.

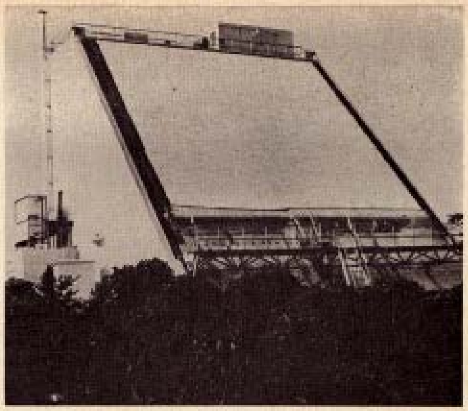

Figure 3 — ESAR — An electronic scanning L-band radar. The rectangular panels on the sloping face contain over eight thousand antennas imbedded in plastic.
(*Courtesy of the Bendix Corporation*)

C. *"Passive-Element" and "Active-Element" Arrays*

Any of the foregoing arrays can be constructed in such a manner that no "active"+ components are introduced into the system until after (using receiving terminology) the beam terminals of Figures 4 and 5. Such arrays will be referred to as "passive-element" arrays. That is, one could realize an array radar with such techniques "merely" by the replacement of the antenna assembly of a conventional radar by an array assembly of the proper number of elements and the installation of the necessary control equipment. While such a replacement permits the use of electronic ("inertialess") scanning, it may lead to decreases in transmitted power and receiver sensitivity due to increased RF losses. Further, the phase shifters themselves may be lossy and/or power limited.

An appreciable extension of radar performance can be obtained by integrating the active electronics into the array itself, enlarging our previous concept of an "element" to include part or all of a radar transmitter and/or receiver, as schematically indicated in Figure 7. Such an array will be referred to here as an *active-element* array. The active electronics associated with each element "module" may range from a simple single-stage amplifier (medium to high power for active-element transmitting arrays and/or a low-noise amplifier for active-element receiving arrays) with associated phasing devices, as indicated in Figure 7, to an almost complete radar, as indicated in the block diagram of Figure 8. To impart some physical significance to this concept, some experimental active-element 900 Mcps modules, in which little attempt has been made at compact packaging, are shown in Figure 9[2,3].

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PHASED-ARRAY RADARS: PAST, ASTOUNDING BREAKTHROUGHS AND FUTURE TRENDS

Phased-array radars have seen ever increasingly wider use around the world over the last five decades. In recent years, they have seen breakthroughs that led to capabilities not possible in the past. This is exemplified by the development of GaAs integrated microwave circuits called monolithic microwave integrated circuits (MMIC) that make it possible to build active electronically scanned arrays (AESA) that have lighter weight, smaller volume, higher reliability and lower cost. These developments have reached the point where it is now possible to build a low-cost 35 GHz phased array for a missile seeker costing $30/element (total cost of array including all electronics divided by the number of elements). This is made possible because integration allows the whole T/R module to be put on a single chip. For some applications, it will soon be possible to put multiple receivers or transmitters on a single chip. The advances provided by Moore's Law have now made it feasible to do digital beam forming with all its numerous advantages. This article describes these advances and also covers the potential for GaN and SiC chips that have the capability of higher peak power by a factor of ten than GaAs chips, arrays with instantaneous bandwidths of up to 33:1, SiGe low-cost T/R modules and low-cost MEMS arrays. A real radar application for multiple-input multiple-output (MIMO) has been demonstrated by MIT's Lincoln Laboratory, which allows the coherent combining of two radars to achieve a 9 dB increase in sensitivity. MIMO also makes possible the optimum removal of clutter in over the horizon (OTH) and airborne radars by permitting adaptive control of the transmit antenna pattern in the receiver.

Over the last five decades since the formation of the *Microwave Journal*, phased-array radars have seen remarkable advances and wide proliferation around the world. This is exemplified in ***Figures 1***, ***2*** and ***3***, which give just a few examples of the phased arrays deployed over the last 50 years and under development in recent years. Back in 1957 there were just a few array radars. John Allen's article, "Array Radars: A Survey of Their Potential and Their Limitations,"[24] first published in *Mi-*

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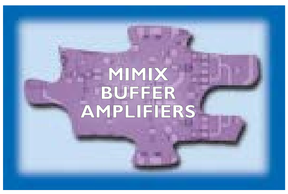

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CMM9000-QT	1.5-6	15	5.5	+15	+25	60 @ 6.0
CMM4000-BD	2-18	8	4.5	+19	+29	115 @ 5.0
XB1007-QT	4-11	23	4.5	+20	+30	100 @ 4.0
CMM0511-QT	5-14	20	-	+11	+22	90 @ 6.0
XB1008-QT	10-21	18	5.5	+20	+30	100 @ 4.0
CMM1118-QT	11-20	20	-	+14	+22	90 @ 5.0
XB1004-BD (Low Noise/Power)	16-30	20 / 21	2.2 / 3.2	+14 / +19	+24 / +29	90 @ 4.0 / 180 @ 6.0
XB1005-BD (Low Noise/Power)	35-45	19 / 23	2.7 / 3.7	+13 / +16	+23 / +26	50 @ 3.5 / 154 @ 4.5

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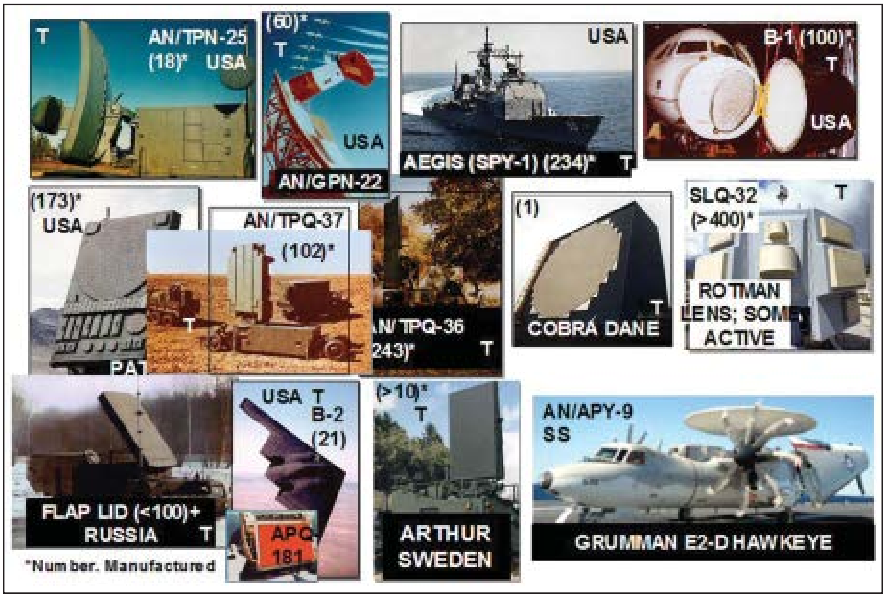


Fig. 1 Example tube (T) and solid-state (SS) passive phased arrays having large productions.[1]

crowave Journal in May of 1962, only showed the experimental L-band electronically steerable array radar (ESAR) that was the predecessor of the FPS-85. In recent years there have been many important breakthroughs in phased-array technology that bode well for the future of phased-array radars.[1,29–36] This article covers some of the past developments and the exciting recent new breakthroughs. The past and recent breakthroughs covered are listed in ***Table 1***.

GaAs MMIC T/R MODULES

Defense companies have successfully applied MMICs to AESA radars over the last decade.[1] The MMIC APG-79 AESA radar on the F/A-18 E/F allows simultaneous air-to-air and air-to-ground modes (see Figure 2b).[25] This means the aircraft can defend itself while at the same time deliver weapons to the target. This is achieved with only a small increase in the cost of the radar over the older mechanically scanned system.[(ibid)] AESA has permitted the Wedgetail AESA L-band arrays to be placed on the top of a Boeing 737-300 for the Royal Australian Air Force without the need of a rotodome, such as used on E-3 Sentry airborne warning and control system (AWACS) aircraft (see Figure 2b). Wedgetail provides 360° coverage; the two back-to-back dorsal arrays provide ±60° coverage broadside while the antenna above them provides endfire coverage of ±30°.

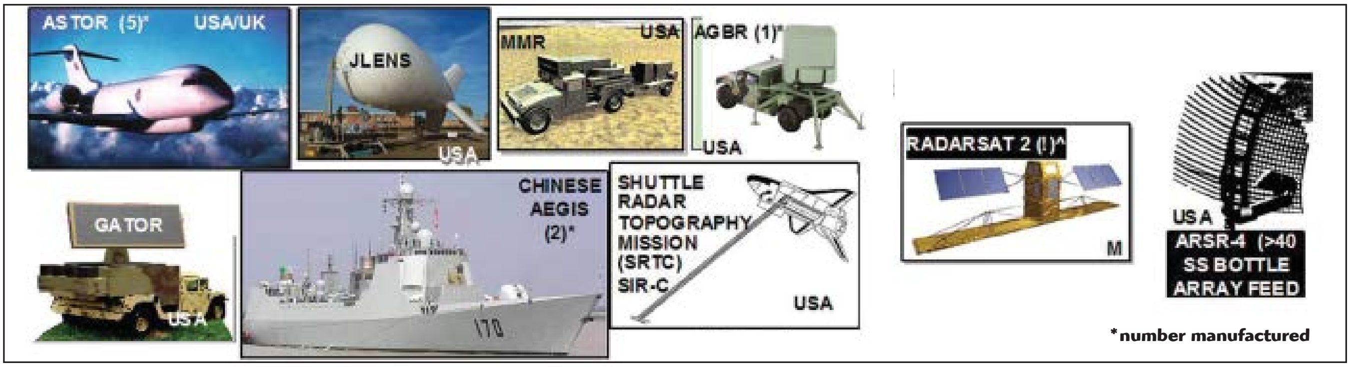
SEA-BASED X-BAND (SBX) RADAR

The 24-story-high Sea-based X-band (SBX) radar, shown in ***Figures 4*** and ***5***, is a new wonder of the world.[26] Part of the US Ground-based Midcourse Defense anti-ballistic-missile system, it is the most powerful phased-array radar ever produced.

LOW-COST PHASED ARRAYS

Who said AESAs have to be expensive? On Defense Advanced Research Projects Agency (DARPA) funding, the feasibility of a low-cost, $19 K, 35 GHz array was demonstrat-

Fig. 2 Example solid-state discrete (D) and MMIC (M) active arrays.



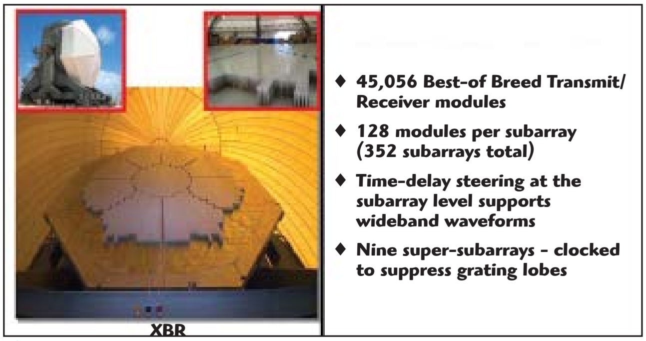
▲ *Fig. 3 Other phased array systems developed or under development.*

ed (see ***Figure 6***).[2] DARPA also funded development of a $10 X-band, 10 mW, single-chip T/R module.[3] A 76 GHz photoetched Rotman lens array costing only a few dollars was developed for automotive cruise control.[8]

TABLE I BREAKTHROUGHS
• Phased arrays everywhere
• GaAs MMIC
• Sea-based X-band (SBX) radar
• 35 GHz $19 K active phased array
• Low-cost MEMS phased array
• GaN, SiC
• SiGe, CMOS
• Digital beamforming
• Packaging and assembly
• MIMO
• Ultra-wideband arrays
• Adaptive arrays
• Space-time adaptive processing (STAP)
• Tube advancements
• Solid-state "bottle" phased-array radars
• Software for design of phased arrays

- **Purpose: Tracking and discrimination radar for Ground-based Midcourse Defense (GMD)**
- **Displacement: 50,000 tons; 250 ft (~24 stories) high**
- **Radome: 103 ft high, 120 ft diam., 18,000 lbs**
- **Radar: X-band phased array, 65% populated**

▲ *Fig. 4 Sea-based X-band (SBX) radar.*



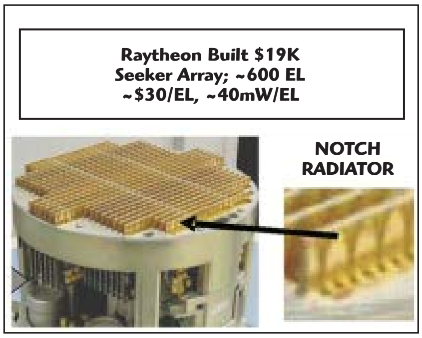
▲ *Fig. 5 XBR array architecture.*

LOW-COST MEMS PHASED ARRAY

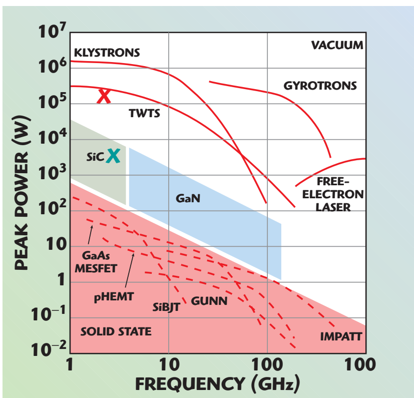
If only we had a low loss phase shifter. Then we could go back to the passive-architecture electronically scanned phased array with one module feeding many phase shifters (10, for example). This could potentially reduce the cost of an electronically scanned phased array by a factor of about ten. Micro-electromechanical systems (MEMS) offer this promise. MEMS switches have improved their reliability by three orders of magnitude over what was reported in October 2003[3] to a life of 600 billion switches.[4,5] There is still need for improvement in the loss. The loss through a four-bit phase shifter used in a 1-D scanned radome antenna space-fed lens (RADANT) is ~1.25 dB. Two lenses are needed for a 2-D scan so that the two-way loss for a 2-D scanned RADANT array would be ~5 dB, but progress is being made.[5]

GaN AND SiC CHIPS

Wide bandgap GaN and SiC MMIC chips offer the potential of one to two orders increase in T/R module power (see ***Figure 7***).[27] ***Table 2*** summarizes the major advantages of GaN. ***Tables 3*** and ***4*** compare GaN with GaAs. This technology would make it possible to upgrade an existing AESA by replacing the GaAs T/R modules with GaN or SiC T/R modules having ten times the power. This provides either a ten times improvement in search volume



▲ *Fig. 6 No low-cost phased array—not true anymore.*



▲ *Fig. 7 State-of-the-art solid-state and tube devices.*

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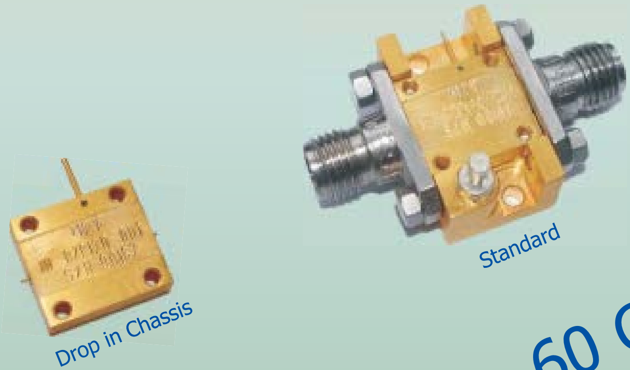

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or a 78 percent increase in track range.[28] CREE provides commercial SiC hybrid devices putting out 10 to 60 W for up to 4 GHz and GaN hybrid devices putting out 15 to 120 W from UHF to 40 GHz.[16] Their goal is to provide in one package 550 W peak and 30 to 40 W average linear power output using a single-stage FET. CREE supports the design of MMIC SiC and GaN chips. For GaN MMIC they provide 60 W saturated from 2.5 to 4 GHz and 25 W saturated from 5 to 6 GHz. See References 16–18 for detailed surveys of state-of-the-art on GaN and SiC.

SiGe CHIPS

SiGe has the advantage of using Si as a substrate, the technology of the low-cost, commercial integrated-circuit industry and whose extensive resources can be drawn upon. It offers the potential of higher performance at low cost. SiGe does not compete with GaAs with respect to microwave output power or noise figure. It offers low cost and the ability to integrate many functions on a single chip. In addition to microwave power amplifiers and a low-noise figure receiver on one chip, it can have A/Ds and digital circuitry. It can have CMOS on the same chip, Si CMOS. GTRI is

TABLE II

GaN TECHNOLOGY ADVANTAGES

GaN has the highest power density of any existing technology
- enables reduced chip size – lower cost for a given power
- smaller FET size enables broader bandwidth because of higher impedance

GaN capable of higher operating voltage
- more efficient power system

GaN on SiC has a superior thermal conductivity compared to GaAs
- maintain moderate channel temps at high power

TABLE III

ADVANTAGES OF MMIC GaN OVER GaAs MMIC

- Provides system advantages re: weight, cooling, prime power, cost, sensitivity, range
- 28 V vs. 10 V at 2× current (I) provides 5–10× power with ~ same gain and efficiency as GaAs
- High voltage GaAs PHEMT at 10 to 20 V at lower I provides only 1.5 to 2× power. GaN more compact for same power. GaN has higher matching Z → wider BW.
- Reliability tests at elevated temperatures indicate 10^6 hr life
- Raytheon goal: 1.25 mm transistor, 40 V, 6.4 W/mm, G = 12 dB, PAE = 60% at 10 GHz

TABLE IV

GaN vs. GaAs COMPARISON

Parameter	GaAs	GaN
Output power density (W/mm)	0.5 to 1.5	3 to 6
Operating voltage (V)	5 to 20	28 to 48
Breakdown voltage (V)	20 to 40	> 100
Maximum current (A/mm)	~ 0.5	~ 1
Thermal conductivity (W/m-K)	47	390(Z)/490 (SiC)


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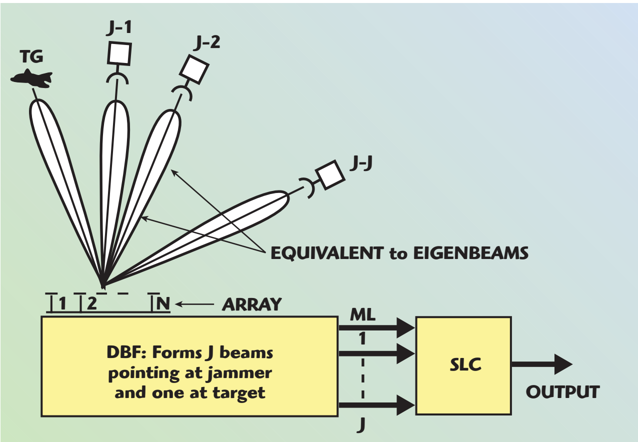
▲ *Fig. 8 Phased arrays that use digital beam forming.*

CMOS CHIPS

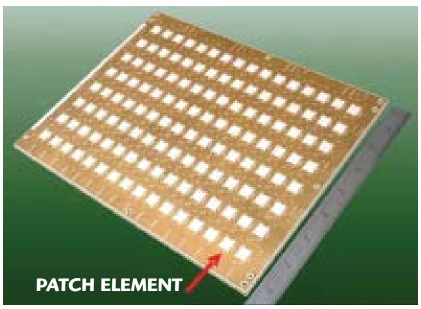
CMOS now operates at microwave frequencies. It, too, uses a silicon substrate and is the technology widely used in the computer industry. It holds the promise of low cost and low power for the receiver parts of T/R modules. Like SiGe, it has the advantage of allowing the integration of many functions on a single chip, even more so than SiGe. One chip can have RF, IF, baseband, microprocessor, memory, tunable filters and A/Ds —a system on a chip (SOC). It can be combined with GaAs or GaN for the microwave power amplifier and low noise figure receiver. Using GaN has the advantage of being robust enough that a limiter may not be needed. Si together with CMOS offers the possibility of the integration of many receive and/or transmit channels on a single chip.



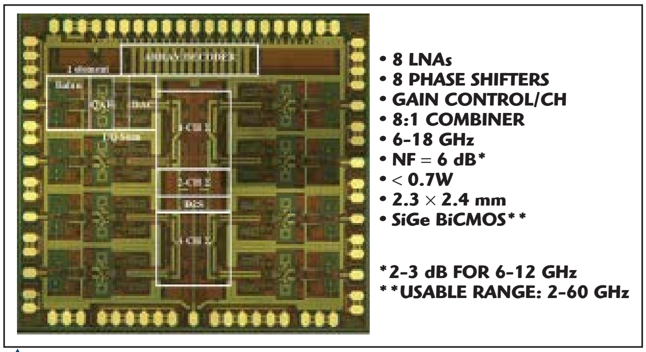
▲ *Fig. 9 Adaptive-adaptive array (Brookner and Howell,* Proc. IEEE, *April 1986, pp. 602-604).*

DIGITAL BEAM FORMING (DBF)

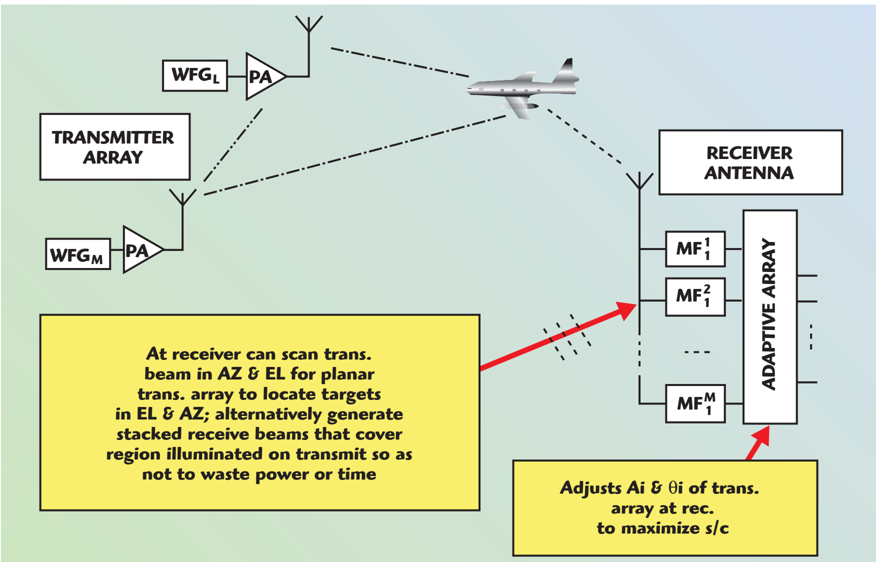
DBF has arrived for microwave AESA radars (see ***Figure 8***). It provides many significant advantages over analog beam forming.[1] For large arrays I used to say DBF is only being developing a SiGe single-chip T/R module for use in an AESA radar. Its initial design had a peak power of > 50 mW using a two-stage power amplifier (PA). Work is under way to achieve 1 W peak by using three stages.[19] The cost per element of an AESA using such a module is expected to be 1/100 that of a GaAs array using high-power T/R modules.[19] The low power per module is made up for in a radar by using a larger array, one that possibly folds on itself.



▲ *Fig. 10 X-band 128-element PCB building block; 2.2 lbs, 7.4" × 1" × 0.21".[20]*



▲ *Fig. 11 Extreme RF integration: single chip with eight receiver channels. (Koh & Rebiez, Univ. of Calif., San Diego,* MWJ, *May,*



▲ *Fig. 12 Optimization of transmit beam at receiver for max S/C.*

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done at subarray. This is no longer true. Elta has done it at the element level for a 2500-element array at S-band, a major breakthrough. Using DBF eliminates the analog combining hardware, analog down-converting and all the errors associated with them. This in turn will lead to ultra-low side lobes. It will allow the implementation of multiple beams pointing in different directions. It will enable the adaptive use of different parts of the antenna for different applications at the same time. It permits simultaneous reduction by a factor of almost two of the transmit RF average search power and search occupancy.[6] The cost savings gained from the simultaneous reduction by a factor of almost two of the transmit RF average search power and search occupancy will be far greater than the increased cost due to the greater required signal processing. At the same time, the search angle accuracy is improved by about 40 percent.[6] DBF will also permit better adaptive-array processing.

ADAPTIVE-ARRAY PROCESSING

The development of adaptive-array processing represents a major step forward in increasing the usefulness of phased arrays. It started with the invention by P.W. Howells of the side lobe canceller (SLC), which he filed on May 4, 1959 (two years after the formation of the *Microwave Journal*) and was patented on August 24, 1965 (US Patent No. 3,202,990). This was followed by the seminal work of S.P. Applebaum published as an internal Syracuse University Research Corp. report in August 1966 and then published in the September 1976 special issue on adaptive antennas of the *IEEE Transactions on Antennas and Propagation*. The SLC nulls out jammers whose signals come in through the side lobes of the main antenna by using auxiliary antennas placed close to the main antenna. These auxiliary antennas receive the jamming signals. By appropriate processing of the signals received by the auxiliary antennas, it is possible to generate jammer signals having the same amplitude and phase as those coming in through the side lobes. By subtracting these signals from the jammed signals in the main channel the jamming interference is cancelled. If a phased array is used to form the main beam, elements forming the array can also be used as the auxiliary antennas, thus serving dual use as elements for the main array and as the auxiliary antennas. It is useful to look at the side lobe canceller physically from another point of view. Specifically, the combination of the main antenna and the auxiliary elements with its processing can be viewed as a new antenna system. As such, its antenna side lobe pattern will have nulls in the directions of the jammers while it also has its main beam pointing in the direction of potential targets to be detected, the direction the main beam would point when no SLC processing is used. Very little is published as to which radars used SLC. This is because of the sensitivity of such information.

For a phased array there exists another more effective way for canceling jammers coming in through the side lobes and even in through the main

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lobe. It is to adjust adaptively the amplitude and phase weights of the array so as to put nulls in the directions of the jammers while maintaining the main beam pointing in the required direction. These amplitude and phase weight adjustments are made based on the jamming signals received by the array and their calculated direction. This system is known as a fully adaptive array processor. Here again it is useful to view the fully adaptive array from another physical point of view. Just as previously we viewed the SLC as an array that puts nulls in the direction of the jammers, we can now go the other way and view the fully adaptive array processor as a SLC.[9,40]

Fully adaptive arrays have been too difficult to implement for large arrays up to now, the hardware and the processing load being too great. To reduce the complexity, consideration has been given to doing fully adaptive array processing at the subarray level. This reduces the number of elements from thousands to a few tens. This is what is done on the UK's Multi-function Electronically Scanned Adaptive Radar (MESAR).[41]

With the advances of DBF, it is now possible to think of achieving the performance of fully adaptive processing without its complexity. In fact, the equivalent jammer suppression of a fully adaptive array without its computation and transient penalties can be achieved. This can be accomplished with adaptive-adaptive array processing.[7] This involves no more than locating digitally where the jammers are, then pointing beams at these jammers (these beams are effectively eigenbeams)[9,10,40] and using these beams as side lobe cancellers for the main beam (see ***Figure 9***). For a 1000-element array having to cope with 10 jammers, we now have to invert a 10 × 10 matrix instead of a 1000 × 1000 matrix and the transient time is reduced by a factor of 100. In a classical fully adaptive array, one does not make use of the location of the jammers. But we can easily determine their location rather than to put on blinders. This method is equivalent to the method of Principal Components.[9] The jammers can easily be located by doing a Fast Fourier Transform across the array. This will not locate jammers less than a beamwidth apart, but for many applications it may be good enough. If better jammer cancellation is needed, then two squinted beams about 3/4 of a beamwidth apart can be used for each located jammer. This is because for closely spaced jammers, less than a beamwidth apart, the eigenbeams are sum and difference beams.[10] Alternately the Music algorithm can be used.[13] Adaptive-adaptive array processing is in the same spirit as the knowledge aided techniques DARPA has been recently funding known as Knowledge Aided Sensor Signal Processor & Expert System (KASSPER),[42] which they have applied to Space-time Adaptive Processing (STAP) discussed in the next section.

STAP

STAP is adaptive-array processing of a pulse Doppler waveform. It provides adaptive nulling of ground clutter and jammers on a moving platform. On a moving platform it places a 2-D Doppler-angle null where the

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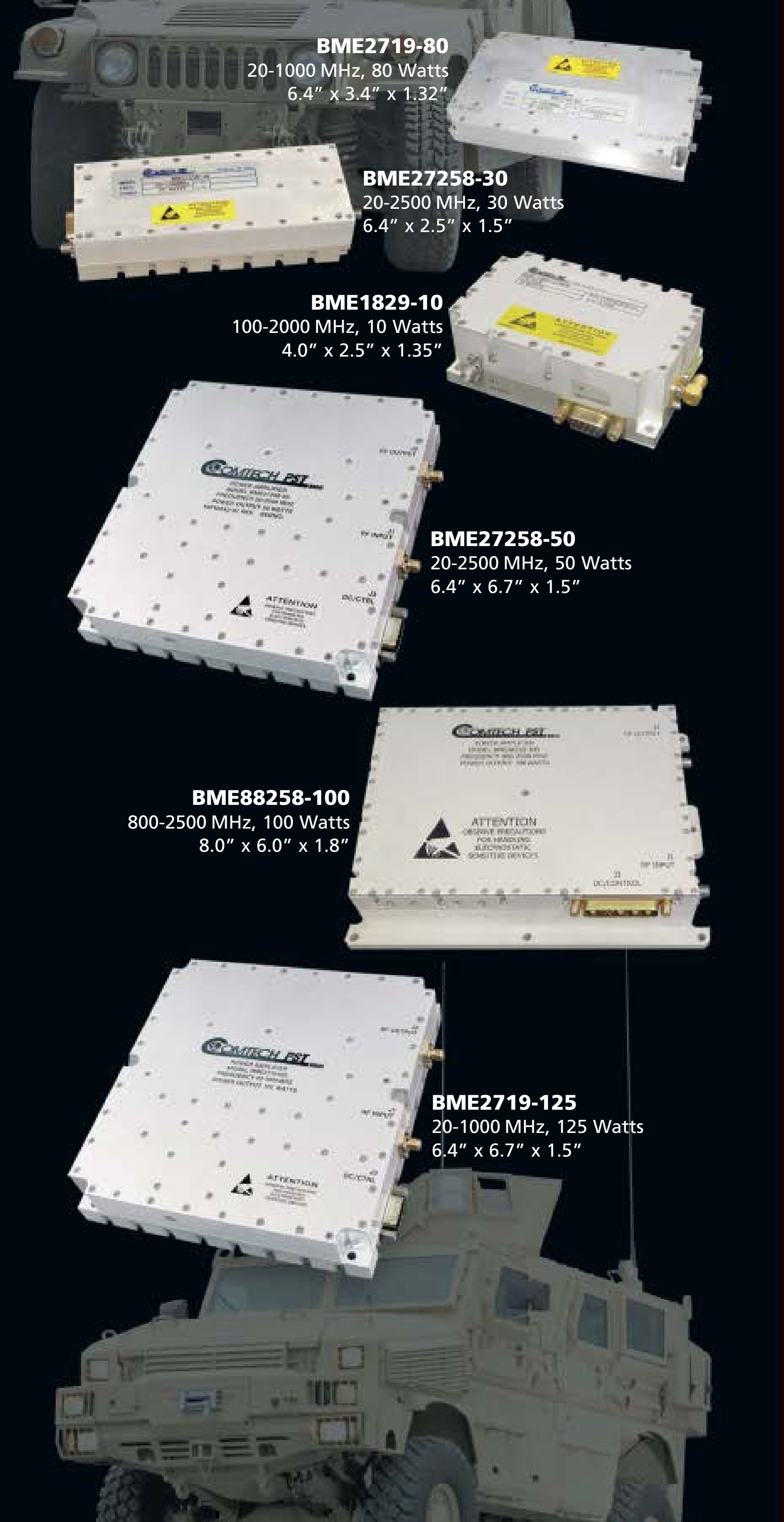

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clutter is.[9] STAP is being used on the new carrier-based E2-D Advanced Hawkeye's AN/APY-9 radar shown in Figure 1.[39] It is used in the littoral environment.[39] It can also be used to cancel out ground clutter for a ground-based pulse Doppler radar.[37]

PACKAGING AND ASSEMBLY

It is now possible to package and assemble active phased arrays having low cost, light weight and small volume. The technique involves the use of commercial printed wiring boards (PCB) and no packages for individual T/R modules. An X-band building-block array of 128 elements and T/R modules was built having a size of 7.4 × 10.1 × 0.21 in.[20] (see ***Figure 10***). Its T/R module chips are flip-chip mounted on the backside of the PCB. No case is used for the modules. An approach using low- and high-temperature cofired ceramic (LTCC/HTCC) for the multilayer board is presented in Reference 21. The ultimate in packaging and RF integration is the placement of many receivers or transmitter channels, or both, on a single chip together with their combiner; see ***Figure 11***, where eight receiver channels are integrated onto a single chip.[23] This should be possible for some radar applications in the near future. Future plans are to integrate 16 to 32 receiver channels on a single chip and 16 transmit channels on a single chip operating from 30 to 50 GHz.[23]

MIMO

Lincoln Laboratory at MIT has demonstrated that one can coherently combine two identical radars to achieve a 9 dB increase in sensitivity.[11] They first transmit from each radar orthogonal waveforms at the same carrier frequency to achieve the coherence on receive. They next use identical waveforms and vary the phase and delays of the transmitted waveforms to achieve coherence on transmit on the target as well as coherence on receive. This provides a 9° dB increase in sensitivity over a single radar. By combining N radars they get an increase in sensitivity of N^3. Another application for MIMO is for OTH, airborne and ground radars. With MIMO it is possible by transmitting orthogonal waveforms from separate transmit elements or subarrays to identify and isolate the signals from each transmit element or subarray. This then permits the adaptive control at the receiver of the transmitter pattern so as to achieve optimum clutter rejection.[15] ***Figure 12*** shows this for the case where an array is used for transmit and a single element antenna is used on receive. By using an array on receive as well as on transmit both the transmit and receive antenna patterns can be adaptively controlled for optimum clutter rejection. Nulls can be placed on the transmit antenna pattern as well as the receive pattern in the direction of strong clutter scatterers.

ULTRA-WIDEBAND ARRAYS

Ultra-wideband array technology is here. This technology allows the use of one antenna for many different applications at different bands. Raytheon has developed a dual-polarized notch-radiating element that has an instantaneous bandwidth from 1.8

to 18 GHz.[3,43] The Georgia Technical Research Institute (GTRI) is developing an array having 33:1 instantaneous bandwidth with potential of 100:1.[38]

TUBE ADVANCEMENTS

Tubes are making major advances.[12,14,22] The availability of powerful software now allows the design of tubes without the need for trial and error. It has been recently shown that it is feasible to build an active 2-D phased array at X-band using TWTs that fit within the array lattice, one TWT per element.[12]

SOLID-STATE "BOTTLE" PHASED-ARRAY RADARS

The new E-2D radar uses a solid state "bottle" transmitter. Its range is 350 nmi.[39]

SOFTWARE FOR THE DESIGN OF PHASED ARRAYS

Powerful software is available now (like HFSS, PARANA and CST) that allows the prediction of the performance of antennas to very high accuracy without the need for costly trial and error constructions and measurements. An array designed in the mid '70s required much trial-and-error and measurements. Today it can be designed without trial-and-error to a small fraction of a dB using Ansoft's HFSS. ■

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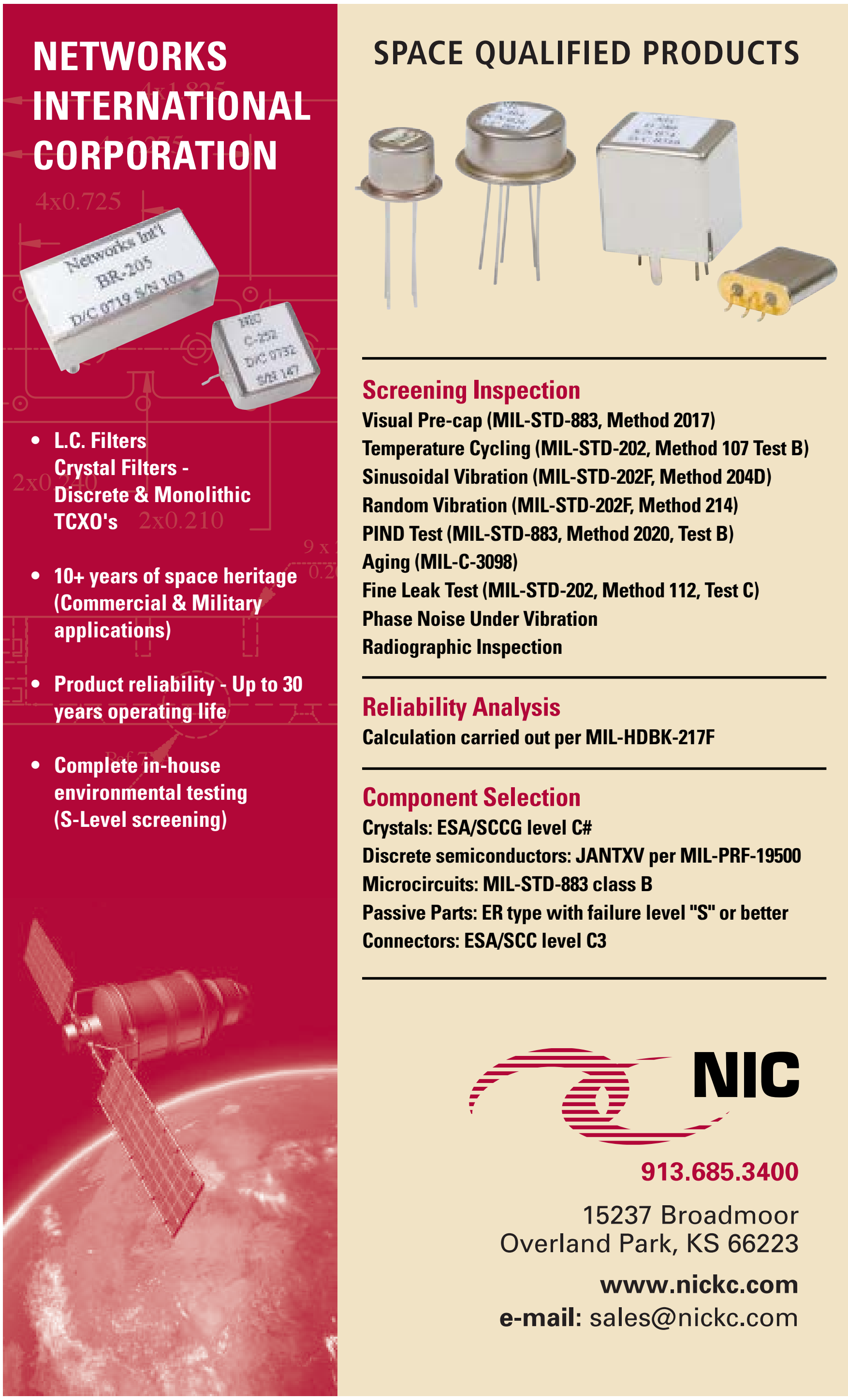

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AML26PN1201	2.0 – 6.0	11	15	-155	-160	-160	-175

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L0408-43	4 - 8	43	20	41.5	45	17
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L1840-27	18 - 40	27	0.5	26	30	2
L2240-28	22 - 40	28.5	0.7	27	30	3
L2630-39	26 - 30	39	8.0	38	40	15
L2632-37	26 - 32	37	5.0	36	38	10
L2640-31	26 - 40	31	1.2	30	30	5
L3040-33	30 - 40	33	2.0	32	33	9
L3337-36	33 - 37	36	4.0	35	40	12
L3640-36	36 - 40	36	4.0	35	40	10

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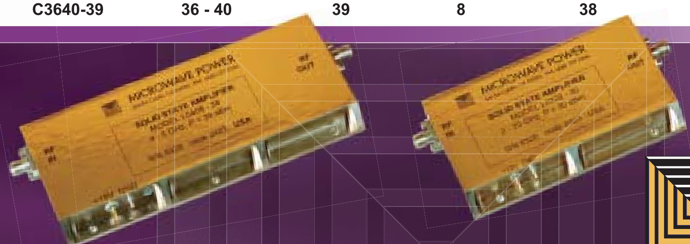
C090105-50	9 - 10.5	50	100	49	1	8.75
C140145-50	14 - 14.5	50.5	110	49.5	2	10.25
C1416-46	14 - 16	46	40	45	0.35	5.25
C1820-43	18 - 20	43	20	41.5	0.25	5.25
C2326-40	23 - 26	40	10	39	0.25	5.25
C2630-45	26 - 30	45	30	44	0.45	5.25
C3236-40	32 - 36	40	10	39	0.25	5.25
C3640-39	36 - 40	39	8	38	0.24	5.25



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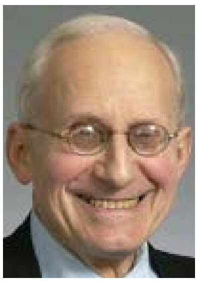

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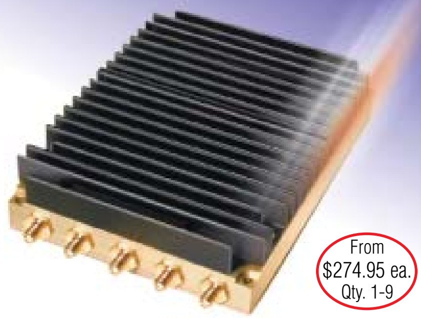

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5020 to 5145 MHz

VCO model ZX95-5150A+ delivers +3.5 dBm typical output power from 5020 to 5145 MHz. The 50 Ω VCO offers excellent spectral purity, with phase noise of -104 dBc/Hz offset 10 kHz from the carrier and -146 dBc/Hz offset 1 MHz from the carrier. Harmonics are typically -15 dBc and spurious are typically -90 dBc. The VCO, which is well suited for point-to-point radios, wireless communications, and test equipment, has typical tuning sensitivity of 75 to 90 MHz/V for tuning voltages of 0.5 to 5.0 V and a 3 dB modulation bandwidth of 120 MHz. It is supplied in a rugged unibody metal housing 1.20 x 0.75 x 0.46 inches with SMA connector, and draws 32 mA maximum from a +5 VDC supply.

RoHS compliant.

RF Transformer
4900 to 5875 MHz

Based on advanced Low temperature co-fired ceramic (LTCC) technology, model NCS2-592+ is a miniature RF transformer that operates from 4900 to 5875 MHz. The 50 Ω surface mount RF transformer provides a secondary/primary impedance ratio of 2 with fullband insertion loss of typically 1 dB. Ideal for radar and WiMAX systems, it handles input levels to 3 W. The typical amplitude unbalance is 0.6 dB and typical phase unbalance is 5° (relative to 180°). The low cost RF transformer measures just 0.079 x 0.049 x 0.033 inches (2.01 x 1.24 x 0.84 mm).

RoHS compliant.

Linear-Tuning VCO
1950 to 2120 MHz

Surface mount VCO model ROS-2130-719+ features linear tuning from 1950 to 2120 MHz. It supplies +1 dBm typical output power with phase noise of typically -108 dBc/Hz offset 10 kHz from the carrier and -148 dBc/Hz offset 1 MHz from the carrier. Harmonics are -16 dBc or better and spurious levels are typically -90 dBc. The 50 Ω VCO is well suited for wireless applications requiring it's wide voltage tuning range of 0.5 to 11.0 V. The miniature 0.5 x 0.5 x 0.18 inch VCO draws maximum 37 mA curent from a +5 VDC supply.

RoHS compliant.

Highpass Filter
5.0 to 10.1 GHz

Highpass filter model VHF-4400+ passes signals from 5.0 to 10.1 GHz with less than 2 dB insertion loss while providing more than 30 dB rejection for signals from DC to 3.6 GHz. Passband VSWR is typically 1.50:1. The five-section, 50 Ω filter, which handles input levels to 7 W, is ideal for use in transmitters, receivers, and test systems. It features unibody construction for reliability, small size of 1.43 inches in length and 0.410 inches in diameter (36.32 x 10.41 mm), and is supplied with SMA connectors.

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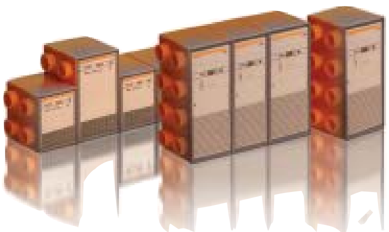

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We're building amplifiers that can grow as your needs change. When you need a more powerful amp, you simply add the power instead of tossing out the old amplifier and starting all over. Smart!

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The TGAR system, for automotive transient immunity testing, is so flexible it can handle most existing specs … such as ISO 7637-2, SAE J113-11 and most US, European and Japanese manufacturer specifications. And it easily adapts to handle most new ones as they emerge.

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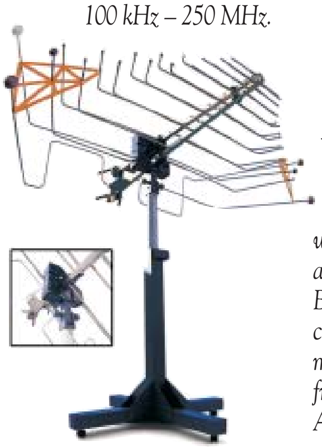
When testing gets tough, ordinary amps fold back and lose power. But AR amps stand up to the toughest conditions with infinite VSWR tolerance. You get every watt of power, every time.

Powerhouse!
When it comes to power and reliability, those who know come to AR. For amplifiers like the 10000A250A, with 10,000 watts of power, 6:1 VSWR tolerance, and a frequency range of 100 kHz – 250 MHz.

Our Conducted Immunity Test Systems Stand Alone!
The CI self-contained RF Conducted Immunity Test Systems have no equals. Nothing even comes close for ease of use, accuracy, flexibility, reliability, or any features that really matter. Testing to CE, MIL and Auto Standards.

Radiant Arrows.
Our unique "bent element" Radiant Arrows are about 60% smaller than standard log periodic antennas. For fields from 26 MHz to 6.0 GHz, the Radiant Arrows offer 6dBi (+ 1.5) gain and produce high fields even in the toughest applications. They can also be calibrated for emissions testing.

Safe Bet!
AR's highly-advanced Starprobe® laser probes have 3 levels of safety to protect your equipment and the reliability of your data. Other probes don't even come close. Frequency covered 5 kHz - 60 GHz, high level of accuracy, laser or battery options.



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No one knows exactly what's next in EMC and Wireless testing. But two things are certain: The demand for more power and higher frequencies will continue. And AR will always be several steps ahead, with the amps and accessories that meet the changing needs.

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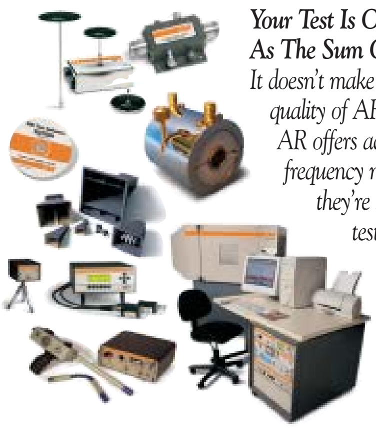
Our battle-tested booster amplifiers cover the broadest frequencies and wave forms and are compatible with virtually every transceiver. We're also supplying some of the most high efficiency modules for jamming applications.

A Wide Range of Modules and Amplifier systems. And Infinite Solutions.

AR Modular RF not only offers modules and rack mounted amplifiers from 10 kHz to 6 GHz (with power that goes from watts to kilowatts), we also provide customer-specific designs and modifications of our products to meet the most demanding requirements and solve the toughest problems.



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It doesn't make sense to compromise the quality of AR amplifiers with inferior parts. AR offers accessories that are power and frequency matched to our amps. And they're specially designed to make testing more efficient.

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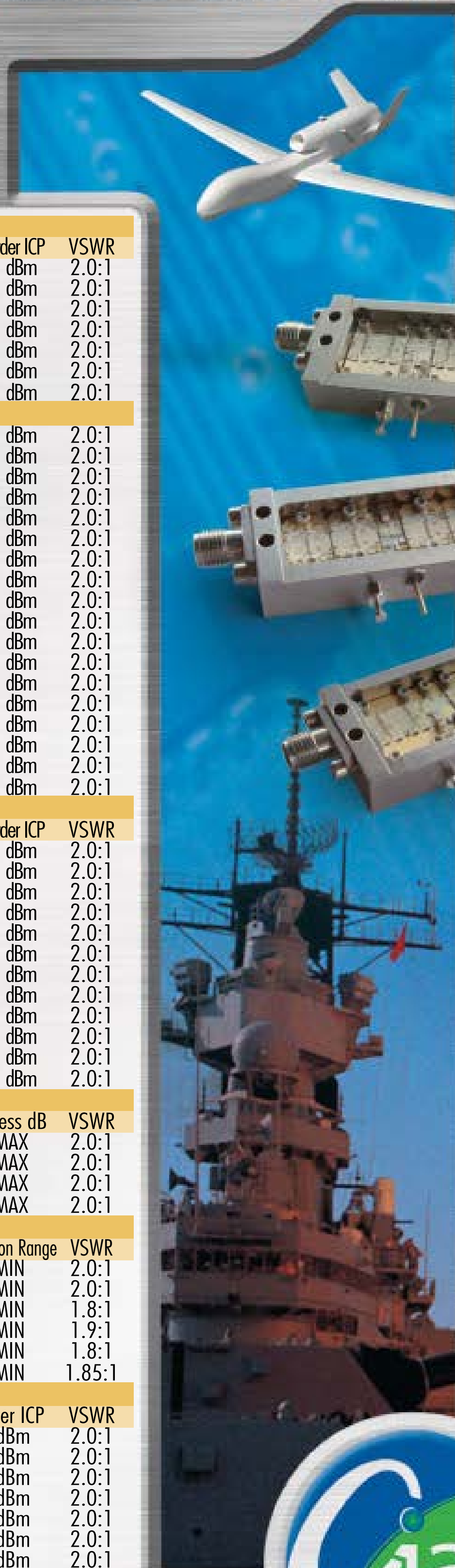

OCTAVE BAND LOW NOISE AMPLIFIERS

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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Modernized GPS Built by Lockheed Martin Declared Operational

The modernized Global Positioning System Block IIR (GPS IIR-M) satellite launched from Cape Canaveral has been declared fully operational for military and civilian navigation users around the world, following a successful on-orbit checkout by a combined US Air Force (USAF)/Lockheed Martin team. The satellite, designated GPS IIR-17M, is the fourth in a series of eight Block IIR-M satellites that bring new capabilities to military and civilian users of the GPS system. Each GPS IIR-M satellite features a modernized antenna panel that provides increased signal power to receivers on the ground, two new military signals for improved accuracy, enhanced encryption and anti-jamming capabilities for the military, and a second civil signal that will provide users with an open access signal on a different frequency.

"With a disciplined approach, proven processes and a strong industry-government partnership, the team once again demonstrated its ability to rapidly move another high-performance GPS IIR-M spacecraft into operations for the user," said Don DeGryse, Lockheed Martin's vice president, Navigation Systems.

Lockheed Martin's operation team concluded the on-orbit deployment and checkout of all spacecraft systems in just over six days, allowing the Air Force Space Command's 2nd Space Operation Squadron (2 SOPS) based at Schriever Air Force Base, CO, to conduct the navigational payload initialization. The satellite was subsequently declared operational for both civil and military users. "The team's focus on operational excellence and mission success is at the heart of this program and we look forward to working side by side with our customer to sustain this critical system for military and civil users worldwide," DeGryse said.

The satellite joins three IIR-M satellites and 12 other operational satellites within the current 28-spacecraft constellation. The team prepared the fifth GPS HR-M satellite for its scheduled launch on December 20, 2007, from Cape Canaveral. The Global Positioning Systems Wing, Space and Missile Systems Center, Los Angeles Air Force Base, CA, is planning to launch the three remaining GPS IIR-M satellites in 2008, one of which will include a new demonstration payload that will temporarily transmit a third civil signal, known as L5. Lockheed Martin is also leading a team, which includes ITT and General Dynamics, in the competition to build the US Air Force's next-generation GPS Block III. The new program will improve position, navigation and timing services for the warfighter and civil users worldwide, and provide advanced anti-jam capabilities yielding improved system security, accuracy and reliability. The USAF's Global Positioning Systems Wing is scheduled to award a multi-billion dollar development contract in early 2008.

Northrop Grumman to Provide US Army with Multiplexer Antenna Systems

Northrop Grumman Corp. has received a follow-on contract from the US Army Communications and Electronics Command to provide soldiers additional Frequency Hopping Multiplexers (FHMUX) antenna systems. The primary function of the FHMUX is to reduce the number of antennas while providing RF isolation between multiple frequency hopping radios. The FHMUX operates across the 30.0 to 87.975 MHz band and has the ability to combine up to four Single Channel Ground and Airborne Radio System (SINGARS) transceivers in a single antenna. The award, valued at $20 M, represents the fifth production delivery order and brings the total contract value to $90 M to Northrop Grumman's Government Systems Division under this indefinite delivery, indefinite quantity contract, originally awarded in 2005.

"The TD-1456/VRC FHMUX greatly reduces interference from other radios while reducing the visual target signature of the command and control platform," said Martin Simoni, site director of Northrop Grumman's Xetron facility. "Simultaneous transmissions from antennas that are in close proximity to each other often result in self-jamming, greatly reducing the effective range of communications. This phenomenon, sometimes referred to as cosite interference, is mitigated with the use of FHMUX that restores up to 90 percent of the range performance." Northrop Grumman will produce an additional 230 FHMUX systems and 1005 spare assemblies. Work will be performed at the Northrop Grumman Xetron facility in Cincinnati, OH.

Harris Team Completes Weather and Radar Processor System Transition to FAA

Harris Corp. has completed the transition of the Federal Aviation Administration's (FAA) weather radar data in the continental US to the FAA Telecommunications Infrastructure (FTI) network, enabling air traffic controllers to receive a much greater volume of weather radar information faster then ever before. The Weather and Radar Processor (WARP) system provides the FAA with the software tools to consolidate weather data from several sources into a single, integrated, real-time display for air-traffic operations in the continental US, Alaska and Puerto Rico. WARP's digital capability supports quicker turnaround to ensure that controllers have the most accurate and up-to-date information. Under contracts awarded in 1996 and 2005, Harris developed, installed and is currently supporting WARP systems at the FAA's 21 Air Route Traffic Control Centers, the Air Traffic Control System Command Center and the William J. Hughes

Technical Center. The transition of the WARP system is another important milestone in the progress of the FTI program. During the 15-year FTI program, Harris is upgrading and improving telecommunications and operations functions at more than 4000 FAA facilities nationwide, and providing the FAA with a more secure, more efficient network that is expected to save $600 M over the life of the program.

Raytheon Successfully Tests New Air-launched Missile Defense System

Raytheon Co. has successfully flight-tested a key component of the Network Centric Airborne Defense Element (NCADE) missile-defense system with the intercept of a test ballistic missile. The test at White Sands Missile Range, NM, demonstrated the NCADE's infrared seeker's ability to acquire and track a ballistic missile target in the boost phase. The NCADE is an air-launched weapon system designed to engage short- and medium-range ballistic missiles in the boost and ascent phases of flight. The NCADE provides an interim or near-term solution to boost- and ascent-phase threats. "This test provides clear evidence that the NCADE seeker is a viable solution against a boosting ballistic missile threat," said Mike Booen, Raytheon Missile Systems vice president of Advanced Missile Defense. "NCADE fills a critical niche in the Ballistic Missile Defense system and provides a revolutionary, low-cost approach to interceptor development and acquisition."

A US Air National Guard F-16 test aircraft from the Air National Guard Air Force Reserve Command Test Center, Tucson, AZ, launched the AIM-9X airframe that carried the NCADE seeker. The NCADE interceptor leverages many proven components and technologies, including the aerodynamic design, aircraft interface and flight control system of Raytheon's Advanced Medium-Range Air-to-Air Missile (AMRAAM). The commonality with the AMRAAM enables the NCADE to launch from a wide variety of aircraft. The NCADE's small size enables it to be carried by and launched from smaller unmanned aerial vehicles, providing a potential operational advantage. The NCADE also leverages proven imaging-infrared seeker components from existing Raytheon production programs. This enables a potentially rapid development and fielding path. Last year, Raytheon teammate Aerojet successfully tested the NCADE second-stage axial-propulsion system, demonstrating the maturity of this new propulsion system. Future testing will improve the missile's divert and attitude-control systems. ■


TEST+MEASUREMENT

Trusted Borders Contract with UK Home Office

Trusted Borders, a consortium of companies led by Raytheon Systems Ltd. of the UK and including QinetiQ, has signed a contract with the UK Home Office to develop and implement the nation's e-Borders project, an advanced border control and security programme. Work has already begun, building upon the country's current pilot programme for border control and expanding it into a fully flexible, scalable and robust e-Borders capability within two years.

Ninety-five percent of the work will be carried out in the UK. The prime contractor for the consortium is Raytheon, which will be responsible for systems integration, travel services and overall project management. QinetiQ is responsible for security accreditation and human factors. The international defence and security technology company is a specialist in designing customer-facing processes and secure systems that comply with UK Government requirements.

Other supporting members of the Trusted Borders consortium are leaders in their respective fields who bring a strong record of performance and delivery to the e-Borders programme. They are: Serco – responsible for infrastructure and service management; Accenture – leading the training of end users of the system and helping to measure the overall business benefits of the programme; Detica – in control of intelligence and analytics services; Capgemini – responsible for the development of business; and Steria – responsible for the development of the Agency interfaces.

ASD President Offers European Vision

Addressing the French Senate Defence Commission, the President of the AeroSpace and Defence Industries Association of Europe (ASD), Åke Svensson, set out the industry's vision for the future in terms of defence and security industrial activities in Europe. He underlined the aerospace and defence industry's high content of cutting-edge technology, which contributes to the wider competitiveness and quality of life in Europe, as well as the global context.

He stated, "Creating the Single European Defence Equipment Market will be a most important contribution to the required level of long-term affordability of the European defence effort. Future defence capability will also require new technologies that we do not master today. European spending on R&D is lagging behind the US significantly. Europe needs to spend more, and to spend wisely, so that its industrial capability is built up for the future.

"Development in the right direction in these three areas will result in a reshaped and even more competitive European Defence Industry including an effective pan-European supply chain, securing an autonomous European alternative in the long term."

Wavecom Joins MOV'EO Hub

To employ its wireless communications expertise to improve vehicle communication and safety by promoting mobility and services, Wavecom S.A. has become a member of the MOV'EO competitiveness hub. The hub groups together a number of French players in the transport and automotive sectors for promoting economic and industrial development. As a member, the company will specifically make technological contributions to two of the strategic focuses of the hub.

The first is the road safety emergency call initiative, where Wavecom will concentrate efforts on tests, assessment and use of embedded communication solutions in vehicles. The initiative has been developed in response to a major European road safety objective aimed at reducing the number of deaths and injuries caused by car accidents by 2010. The company also plans to contribute to the development of cooperative systems between vehicles and infrastructure to allow better information exchange, thus further improving road safety.

The second focus of Wavecom's efforts is mobility and services. The company's technological input, supported by its progress in designing smart wireless electronic communication solutions with its Wireless Microprocessor® aims to support development of new business models for better use of transport services by encouraging data exchange between vehicles and traffic with transport centres.

Terma and NLR Open European EW Centre

Danish defence company Terma and the National Aerospace Laboratory (NLR) of the Netherlands have signed a cooperation agreement within the framework of establishing a European Electronic Warfare Competence Centre. The company's decision to establish the centre is based on more than 20 years of close relations and cooperation with the Royal Netherlands Air Force (RNLAF) as well as NLR.

The EW Competence Centre is scheduled to be established by the spring of 2008, starting up in existing Terma B.V. facilities in Leiden as well as at NLR in Amsterdam. According to the plan, maintenance, repair, and overhaul (MRO) related activity will be established in the Woensdrecht area in that timescale to service the EW systems in use with the RNLAF.

The activities that the competence centre will provide includes MRO of Terma and third party products, integrated logistics support, modification and upgrade programmes, technical support and outsourcing services, EW training services and development and support of "mission-critical" systems and applications.

As a partner, the capabilities that NLR will contribute are mechanical or electronic design, prototyping and low-rate production, development and testing of embedded and application software, functional and environmental system testing, aircraft integration support, obsolescence management and modification and/or upgrade programmes.

Infineon has Mid-range Cars on its Radar

Price and size constraints have limited the use of automotive radar systems to higher-end, luxury vehicles. That is set to change with Infineon Technologies' announcement of a new family of radar system ICs (RASIC™), which could bring long- and medium-range automotive radar to mid-range cars as soon as mid-2010.

With the European Union planning to continue its safety campaign aimed to further improve road safety and decrease the number of traffic accidents by 50 percent by 2010, there is a clear need for the large-scale introduction of integrated safety systems that can help reduce accident risk in critical situations. Long and medium range radar systems can play a valuable role by identifying obstacles and automobiles ahead, despite visibility.

Infineon's RXN7740 radar chip has the capability to meet these criteria. It is a highly integrated front-end chip for the 76 to 77 GHz frequency range, which includes function blocks for the oscillator, the power amplifier and four mixers for multiple antennas. Compared to current radar systems, which implement these functions discretely, the radar chip is claimed to enable vendors to shrink their radar systems to a quarter of the current size, while reducing system costs for the radio frequency module by more than 20 percent.

The front-end chip uses a manufacturing technology based on silicon germanium (SiGe) with a transit frequency of 200 GHz. The technology, developed with the aid of Germany's Federal Ministry of Education and Research (BMBF) as part of the KOKON project, has been designed and qualified specifically for automotive use. ■

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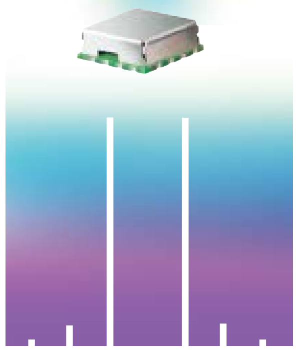
MIXERS

2 to 2500 MHz



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TYPICAL SPECIFICATIONS

Model No.	Frequency (MHz) RF	LO	IF	LO Pwr. (dBm)	IP3 (dBm)	1dB Comp. (dBm)	Conv.Loss (dB)	Isolation (dB) L-R	L-I	Price $ ea. Qty.(1-9)
LAVI-9VH+	820-870	990-1040	120-220	+19	+36	+23	7.2	46	46	15.95
LAVI-10VH+	300-1000	525-1175	60-875	+21	+33	+20	6.3	50	45	22.95
LAVI-17VH+	470-1730	600-1800	70-1000	+21	+32	+20	6.8	52	50	22.95
LAVI-22VH+	425-2200	525-2400	100-700	+21	+31	+20	7.7	50	45	24.95
LAVI-2VH+	2-1100	2-1100	2-1000	+23	+34	+23	7.5	48	47	24.95
LAVI-25VH+	400-2500	650-2800	70-1500	+23	+32	+20	7.5	50	45	24.95

U.S. Patent Number 6,807,407

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Custom sizes available, consult factory.

SMA Female | SMA Male | N-Type Male

RoHS COMPLIANT

Frequency Range: DC-18 GHz, Impedance: 50 ohms

Models	Connector Type	Length (Ft.)	Inser. Loss (dB) Midband Typ.	Return Loss (dB) Midband Typ.	Price $ ea. Qty.(1-9)
Male to Male					
CBL-1.5FT-SMSM+	SMA	1.5	0.7	27	68.95
CBL-2FT-SMSM+	SMA	2	1.1	27	69.95
CBL-3FT-SMSM+	SMA	3	1.5	27	72.95
CBL-4FT-SMSM+	SMA	4	1.6	27	75.95
CBL-6FT-SMSM+	SMA	6	3.0	27	79.95
CBL-10FT-SMSM+	SMA	10	4.8	27	87.95
CBL-12FT-SMSM+	SMA	12	5.9	27	91.95
CBL-15FT-SMSM+	SMA	15	7.3	27	100.95
CBL-2FT-SMNM+	SMA to N-Type	2	1.1	27	99.95
CBL-3FT-SMNM+	SMA to N-Type	3	1.5	27	104.95
CBL-4FT-SMNM+	SMA to N-Type	4	1.6	27	112.95
CBL-6FT-SMNM+	SMA to N-Type	6	3.0	27	114.95
CBL-15FT-SMNM+	SMA to N-Type	15	7.3	27	156.95
CBL-2FT-NMNM+	N-Type	2	1.1	27	102.95
CBL-3FT-NMNM+	N-Type	3	1.5	27	105.95
CBL-6FT-NMNM+	N-Type	6	3.0	27	112.95
CBL-15FT-NMNM+	N-Type	15	7.3	27	164.95
CBL-20FT-NMNM+	N-Type	20	9.4	27	178.95
CBL-25FT-NMNM+	N-Type	25	11.7	27	199.95
Female to Male					
CBL-3FT-SFSM+	SMA-F to SMA-M	3	1.5	27	93.95
CBL-2FT-SFNM+	SMA-F to N-M	2	1.1	27	119.95
CBL-3FT-SFNM+	SMA-F to N-M	3	1.5	27	124.95
CBL-6FT-SFNM+	SMA-F to N-M	6	3.0	27	146.95

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RF/IF MICROWAVE COMPONENTS

403 Rev I

Massive Global Commercial Market for Sub-5 GHz Silicon RFICs

According to a new report recently released by Engalco, the merchant market for silicon-based RFICs is set to grow rapidly from a global total of around $12 B in 2006 to exceed $29 B by 2014. "The RFIC Report" focuses on the following commercial applications: Active RFID, Bluetooth, cell phones (handsets), SATNAV and WiMAX. All of these end-user applications are considered to be high-volume and forecasts of shipments are included in the report. Silicon-based RFICs in this context are mainly transceiver RFICs built using CMOS or BiCMOS processes and operating at frequencies up to around 5 GHz. In the case of SATNAV, however, the RFICs are receive-only. Also, both active RFID and Bluetooth require only relatively low-power transmitters and this factor reduces the chip selling prices. Some of the chips use SiGe semiconductor. The leading market segment is currently RFICs into cell phones (worth about $11 B annually on a global basis) and this segment retains its lead until 2013, when active RFIDs are expected to overtake them. The global market for RFIDs start fairly modestly at $200 M in 2006, but rise rapidly to reach almost $28 B in 2014. It is widely expected that active RFIDs will be found in a very wide variety of applications—and then in huge volumes—during the next six years. For Bluetooth, RFIC applications markets are relatively modest but, again, rapid growth is forecasted, especially in the case of WiMAX. Markets for RFICs are always by far the largest in the catchall region known as the "Rest of the World" (RoW), which includes China, India, Japan and Korea. Already, most commercial systems are assembled and manufactured in these countries (particularly China), and "The RFIC Report" anticipates this situation will prevail in the future. The RoW markets occupy 78 to 79 percent of the global total. In this report, average selling prices (ASP) and shipments are provided in most instances—again with forecasts to 2014. A total of 74 RFIC manufacturing (or "fabless") companies are identified and 32 of these are profiled in depth. The players that have fabless operations are identified and the entire industry structure is critiqued in detail, including worldwide sales operations.

Asian Chip Manufacturing Capacity Growing at Double-digit Rate

Semiconductor manufacturing in Asia has been increasing at an impressive pace and that trend will continue for at least the next several years, reports In-Stat. Asian semiconductor-manufacturing capacity will increase at a compound annual growth rate of 10.8 percent from 2006 to 2011, the high-tech market research firm says. "The pure-play foundries are becoming more important as outsourcing from integrated device manufacturers is on the upswing," says Mayank Jain, In-Stat analyst. "Pure-play foundries have maintained their lead in developing leading-edge process technologies. DRAM and Flash manufacturing capacity in the region is also witnessing substantial growth."

In-Stat's research report, "Semiconductor Manufacturing Capacity Trends in Asia," covers the Asian semiconductor manufacturing market. It examines the semiconductor manufacturing capacity of Asia as a whole and of individual countries, with a five-year forecast. It also provides an overview of 300 mm capacity in the region. In addition, it provides details such as capacity, process technologies and wafer size for all the leading fabs in the region.

Recent research by In-Stat found the following:

- There were twenty-five 300 mm fabs operational in the Asia Pacific region in 2006.
- Singapore will experience the highest growth rate due to fresh investments from leading memory makers.
- In 2006, Taiwan had the most 300 mm capacity, followed by South Korea.

For more information on this research, please visit: www.in-stat.com.

Wireless Advances Pose Security Challenges, Opportunities

Wireless LAN (WLAN) technology has become a standard part of business networks, and portable computers with Wi-Fi and inexpensive wireless routers have made connectivity even more pervasive outside of the business premises, reports In-Stat. These trends, and growth in the Wi-Fi phone market, pose key security challenges for IT managers, the high-tech market research firm says. Within wireless security, there are two distinct markets: client security to protect data when it is transmitted or stored on portable devices and facility security to monitor the RF environment and enforce policies to protect network operations and assets on the business premises. Together these markets are projected to reach $10.2 B by 2011.

"In early 2007, the Wi-Fi Alliance announced that it had certified nearly 100 Wi-Fi phones," said Victoria Fodale, In-Stat analyst. "Strong continued growth in this market is expected as operator deployments of combined Wi-Fi and cellular solutions increase worldwide."

Recent research by In-Stat found the following:

- Between 2007 and 2011, close to 1.5 billion client devices with WLAN capability will ship.
- By 2011, dual-mode cellular/Wi-Fi phones will comprise almost 50 percent of WLAN clients.
- Many of these devices will be purchased by consumers, not their companies.

$10 B Mobile Video Messaging Opportunity for 2012

Mobile video messaging services are at the center of the technology convergence that is helping mobile customers realize greater levels of self-expression and on-line community participation. This according to Dan Shey, principal analyst at ABI Research. "Mobile video messaging is perfectly positioned to take advantage of the convergence of increased mobile device capabilities and consumers' desire for broader communication options beyond voice," Shey says. "In fact, we expect the opportunity for mobile video services to produce a compound annual growth rate of nearly 60 percent, amounting to $10 B in 2012."

But mobile video messaging is just part of a much bigger portfolio of mobile services that includes video calling, video sharing and mobile TV services. The complexity of the mobile video value chain affects mobile equipment and service suppliers not only in industrialized countries but also in developing regions of the world. Given such complex conditions, ABI Research has created forecasts for uptake of mobile video messaging and telephony services for eight regions of the world: North America, Western Europe, Asia Pacific-Developed, Eastern Europe, Latin America, Asia Pacific-Developing, Middle East and Africa. The industrialized parts of the world with the highest concentration of advanced video devices will see the greatest uptake of mobile video services. However, do not discount the developing regions. Says Shey: "Social networking sites such as Orkut are very popular outside of the US and Europe. Mobile video messaging will facilitate mobile content delivery using a growing base of video recorder devices and established 2.5G networks."

ABI research's recent study, "Mobile Video Communications Services," provides a comprehensive analysis of the global mobile video services market. While the main focus of the report is video messaging and telephony services, video broadcast service market forecasts are also included. The report examines in detail the network and device telecommunication enablers as well as the regional differences for various demand drivers and inhibitors. It is rounded by a review of the role and current activities of value chain participants and market forecasts. Forecast analysis includes video phone penetration and shipments and video services uptake by customer, service type, revenues and penetration for eight different regions of the world. The study forms part of two ABI Research Services: Business Mobility and Mobile Content, which include research reports, research briefs, market data, ABI Insights, the ABI Vendor Matrix and analyst inquiry support. ■


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INDUSTRY NEWS

■ **Dielectric Communications**, a division of SPX and a developer of broadcast antenna systems, announced that the National Academy of Television Arts and Sciences will present the company with a Technology and Engineering Emmy® Award at an awards ceremony during the International Consumer Electronics Show (CES) in Las Vegas, NV, on January 7, 2008. The award recognizes Dielectric's accomplishments in designing ATSC broadcast transmission system RF filters. Dielectric's ATSC transmission filters eliminate spurious emissions that the transmitter may generate outside of the station's allotted channel of operation, keeping the transmission system FCC compliant.

■ **ON Semiconductor Corp.** and **AMIS Holdings Inc.**, parent company of AMI Semiconductor, announced the signing of a definitive merger agreement providing for the acquisition of AMIS by ON Semiconductor in an all-stock transaction with an equity value of approximately $915 M. Under the terms of the agreement, which has been approved by both boards of directors, AMIS shareholders will receive 1150 shares of ON Semiconductor common stock for each share of AMIS common stock they own. The transaction is subject to the approval of shareholders from both companies as well as customary closing conditions and regulatory approvals.

■ **Nitronex**, a designer and manufacturer of gallium nitride on silicon (GaN on Si) RF power transistors for the wireless infrastructure, broadband and military markets, has qualified its new, state-of-the-art manufacturing facility. The move from Raleigh to Durham began in first quarter 2007 and was finished in the second quarter, with qualification testing completed in October. The completed qualification verifies that Nitronex has successfully replicated the process developed in Raleigh at the new Durham fab and is prepared for volume production. The successful qualification completes the relocation of the company into its new 85,000 square-foot R&D and manufacturing facility. This move enhances Nitronex's current and future manufacturing capacity and capability, while also providing additional space for expanding research and development efforts.

■ **FCI**, a supplier of high speed, high density connectors and interconnect systems, and **Amphenol**, a provider of high performance backplane interconnect systems, have entered into second source agreements covering three connector product families: FCI's ZipLine™ connector system, and Amphenol's XCede™ and Crossbow™ interconnect platforms. ZipLine is a high-density connector system with over 80 differential pairs per linear inch on a 25 mm card pitch. This dense packaging also allows extra space for signal routing on the backplane and improved airflow for cooling. The XCede and Crossbow platforms are the high-performance backplane connectors that achieve over 20Gb/sec in a complete system.

■ **Elcoteq SE**, an integrated electronics manufacturing services company with original design manufacturing capabilities in the communications technology field, announced that it has become the global manufacturing partner for **Telsima**, a developer of WiMAX-based broadband wireless access and DCME voice-compression solutions. Elcoteq has started volume manufacturing of Telsima WiMAX CPEs StarMAX 2100 series at its facility in Bangalore, India.

■ **Agilent Technologies Inc.** and **Multiprobe Inc.** announced their intent to expand the companies' strategic partnership. As a result, Multiprobe's Multiscan Atomic Force Prober (AFP), a high-resolution nanoprober, will be sold and supported by Agilent to customers in Asia and Japan. This arrangement strengthens the existing relationship between the two companies and expands Agilent's product offerings to include the industry's leading solution for failure analysis in semiconductor devices.

■ **Palomar Technologies**, a provider of precision automation equipment, process development and assembly services for microelectronics, announced a partnership with **Vision Manufacturing Inc.** (VMI), a contract electronics manufacturer. Through VMI, Palomar Microelectronics will offer printed wiring board (PWB) and surface-mount technology (SMT) services for its customers to supplement the process development, prototyping, and low volume assembly services Palomar Microelectronics provides.

■ **Protium Technologies Inc.** and **Vanu Inc.** have signed a teaming agreement formalizing their business relationship. Under terms of the agreement, Protium will continue to design, develop and manufacture a line of RF front-end equipment to meet the requirements of Vanu's software-defined radio architecture. Protium has been partnering with Vanu on the commercial delivery of its software radio solution that simultaneously operates GSM, CDMA and other standards.

■ **RF Micro Devices** (RFMD), a designer and manufacturer of high-performance radio frequency systems and solutions, announced it is providing its RF3161 quad-band large signal polar modulation (LSPM) EDGE power amplifier (PA) module for the **Huawei** (Shenzhen, China) U120E 3G multi-mode (UMTS/EDGE) handset. The highly integrated RF3161 is packaged in a compact 6 × 6 × 1 mm package. RFMD anticipates new, incremental EDGE enabled handsets will feature its RF3161 as well as its high efficiency RF3159 linear EDGE PA.

CONTRACTS

■ **Raytheon Network Centric Systems** has selected **Tyco Electronics Corp.** as a key supplier on the Multi-Function Radio Frequency System (MFRFS). Raytheon has developed MFRFS as the common radar for Future

Combat Systems manned ground vehicles. This teaming integrates Tyco Electronics' advanced MIL600 connector as the main I/O connector on the Raytheon MFRFS' processor unit. The connector complies with MIL-DTL-83527 and EN3682 and incorporates Tyco Electronics' miniature expanded-beam optical technology.

■ **Lockheed Martin Systems Integration** awarded a $0.7 M contract to **Phase Matrix Inc.** to develop an X-/Ku-band digitally tuned oscillator for the US Air Force's B-2 Spirit stealth bomber. The oscillator will be used to help modernize the B-2's electronic systems. Phase Matrix expects to receive orders for additional spares once qualification of the oscillator has been satisfactorily completed. Phase Matrix' new compact, high-performance digitally tuned oscillator uses low phase noise, fast-settling voltage-controlled oscillators that are digitally linearized to provide high frequency accuracy over the frequency band and temperature range. This high-resolution digitally tuned signal generation module offers low post tuning drift and high purity.

■ **MFG Galileo Composites** (Sparks, NV), a specialist in the design and manufacturing of custom composite radomes and reflectors, has secured funding for a second Defense Advanced Research Projects Agency (DARPA) assignment to advance technology for ground-based radomes. The "Research and Development for RF Performance of Ground-based Radomes" proposal was submitted in response to the Elusive Surface Target Engagement Technology, DARPA/Federal Business Opportunities Broad Agency Announcement 07-15, and selected by DARPA on September 26, 2007. This latest project is a follow on to the company's earlier research and development work for DARPA that primarily addressed durability and maintainability aspects of radome performance. The objective of the follow-on project is to explore new methods that will increase radome RF performance characteristics while decreasing maintenance costs for end users in military, defense and commercial applications.

FINANCIAL NEWS

■ **Tundra Semiconductor Corp.**, a developer of systems-interconnect technologies, reported financial results for the second quarter of fiscal 2008, which ended October 28, 2007. On October 23, the company provided updated revenue guidance for the quarter in the range of $17 M to $18 M. Revenue for the second quarter of fiscal year 2008 was $17.9 M, a 19 percent decrease over the second quarter in fiscal year 2007, and an 11 percent decrease from the first quarter of fiscal year 2008.

■ **Merrimac Industries Inc.**, a designer and manufacturer of RF microwave components, subsystem assemblies and micro-multifunction modules, announced sales from continuing operations for the third quarter of 2007 were $6.6 M, an increase of $1.1 M or 20.2 percent compared to the third quarter of 2006 net sales of $5.5 M.

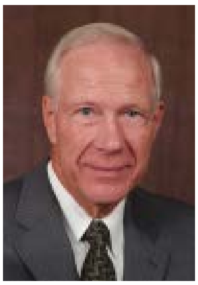
■ **Tower Semiconductor Ltd.**, an independent specialty foundry, announced its revenue for the third quarter of 2007 was $56.6 M, representing an increase of 10 percent when compared to revenue of $51.5 M reported in the third quarter of 2006.

NEW MARKET ENTRIES

■ **Superconductor Technologies Inc.** (STI), a provider of high-performance infrastructure products for wireless voice and data applications, announced it signed a binding definitive agreement for a joint venture with **Hunchun BaoLi Communications Co. Ltd.** (BAOLI) (Hunchun City, China) to manufacture and market STI's SuperLink® interference elimination solution for the China market. The joint venture will be called **Hunchun BaoLi Superconductor Technology Co. Ltd.** (HBST) and will be registered in Jilin Province. Products will be manufactured initially in Shenzhen and ultimately in the Commercial Cooperation Zone located in Hunchun City, Jilin Province. The sales and marketing division will be based in Shenzhen. Under the terms of the agreement, STI will provide an exclusive license in the China market of the enabling technology and BAOLI will provide the manufacturing expertise and financing.

■ **Vanguard Microwave Solutions** is a new startup company specializing in the design and manufacture of ultra-wide bandwidth passive components up to 65 GHz. Vanguard was formed by a group of engineers with a combined experience of more than 50 years in designing, manufacturing and testing. The company currently offers ultra-broadband directional couplers, 90° and 180° hybrid couplers and power dividers, and will design custom components. Find Vanguard Microwave on the Web at www.vanguardmicrowave.com.

PERSONNEL



▲ Louis J. Meyer

■ The Radio Club of America (RCA) presented **Louis J. Meyer**, director of technical marketing, radio frequency (RF), at Andrew Corp., with its 2007 Alfred H. Grebe Memorial Award for outstanding achievement in designing quality electronic components and equipment on November 16 during the 98th Anniversary RCA Awards Banquet at the New York Athletic Club, New York City. The Radio Club of America is the world's oldest radio communications society, founded in 1909 in New York City to promote cooperation among those interested in the advancement and scientific study of radio communications. Meyer is being honored for exemplary contributions to the field of RF communications, which spans industries as varied as missile defense systems to wireless communications. Meyer's 45-year career was spent largely at Decibel Products, a Richardson, TX-based firm specializing in antenna design and manufacturing for the cellular marketplace, which Andrew acquired in 2003. He holds two patents in telecommunications technology, and is currently vice chair of the Telecommunications Industry Association sub-committee TR-8.11, Antenna Systems.

▲ Carmen Losanno

■ Ion Beam Milling Inc. announced that it has appointed industry veteran **Carmen Losanno** vice president of sales. Losanno will lend his 45 years of experience to drive Ion Beam Milling's strategic direction, growth, new business development and all worldwide sales efforts. He joins Ion Beam Milling from Advanced Reproductions, where his last position was vice president of sales.

▲ Christopher A. French

■ Rohde & Schwarz today announced the appointment of **Christopher A. French** as vice president and general manager of Rohde & Schwarz Canada. French is responsible for the overall management of Rohde & Schwarz Canada's operations, including sales of test and measurement equipment, broadcast transmitters, and aerospace and defense products.

▲ Joseph G. Bukowski

■ Aeroflex/MicroMetrics, a manufacturer of RF/microwave diodes and passive semiconductor devices for commercial and military communications, announced that **Joseph G. Bukowski** has recently joined its engineering team in its MicroMetrics Semiconductor Division, Londonderry, NH, as a senior applications engineer. Bukowski brings over 30 years of practical RF and microwave circuit design experience and knowledge utilizing silicon and GaAs-based semiconductors. His particular area of expertise is based in broadband and high power control circuit designs involving PIN diode switches, attenuators and limiters. He is the co-author of several technical microwave publications and US product design patents.

■ SUSS MicroTec, a supplier of precision manufacturing and test equipment for the semiconductor and related markets, has appointed **Wilfried Bair** to the position of vice president strategic business development. Initially he will focus on further developing the company's 3D packaging and 3D integration product portfolio. An expert in 3D technology applications, Bair has many years of management and business development experience in the semiconductor industry throughout Europe, the US and Asia.

■ Fairchild Semiconductor, a global supplier of high performance products that optimize system power, recently appointed **Justin Chiang** senior vice president of the newly formed Power Conversion, Industrial & Automotive Product Group. This new organization includes Fairchild's Power Conversion, High Voltage and Automotive product lines and will focus on leveraging the group's extensive expertise in developing advanced power supply

and power management solutions for this fast growing market segment. Chiang formerly served as Fairchild's vice president of system power within the Analog Products Group. Prior to joining Fairchild he held a variety of technical and senior management positions with Raychem Corp. and Tyco Electronics.

■ Applied Wave Research (AWR), a developer of high-frequency electronic design automation tools, announced that **Rick Bottomley** has joined the company as its chief financial officer (CFO). In his new role, Bottomley will be responsible for the company's global finances, accounting, and fiscal planning activities, as well as helping to evaluate business opportunities and strategies. He joins AWR with over 20 years of experience across all facets of financial management in the high-tech industry.

■ Elcom Technologies Inc., a designer and manufacturer of a wide range of RF solutions for the defense and commercial market, announced the appointment of **Jim Davis** as chief executive officer, reporting to the board of directors. His primary charter is to exploit Elcom's early success derived from its modular RF digital architecture and synthesizer technology. Uri Yaniv will continue his role as CTO and chairman of the board.

■ Ansoft Corp. announced the retirement of **Thomas A.N. Miller**, the company's CFO, effective December 31, 2007. Miller, who is one of the company's founders and has served as CFO since February 2004, will be succeeded by **Shane Emswiler**, Ansoft's vice president of finance. Emswiler is a certified public accountant that joined Ansoft in September 2004 from Ernst & Young, where he was a senior manager in the assurance and advisory practice.

REP APPOINTMENTS

■ **RECOM**, a power supply specialist for DC/DC and AC/DC converters, has appointed **Allied Electronics** as its new distributor for the North American market. Allied Electronics is a small order, high service level distributor of electronic components with 56 sales branches across the United States and Canada. In addition to the 175 lines of on-board DC/DC, AC/DC converter and switching regulator products offered in the new printed catalog, Allied Electronics will now also have fast access to the extended RECOM portfolio of over 10,000 different products.

■ **ANADIGICS Inc.**, a supplier of wireless and broadband communications solutions, announced that it has selected **Rochester Electronics** to be its authorized distributor of discontinued products. Rochester Electronics works with 30 semiconductor manufacturers to provide a reliable aftermarket source for discontinued products. Rochester will continue filling orders for ANADIGICS customers when products reach end-of-life status and beyond. All ANADIGICS products

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SBTC-2-20+	200-2000	50 Ω	3.49
SBTC-2-25+	1000-2500	50 Ω	3.49
SBTC-2-10-75+	10-1000	75 Ω	3.49
SBTC-2-15-75+	500-1500	75 Ω	3.49
SBTC-2-10-5075+	50-1000	50/75 Ω	3.49
SBTC-2-10-7550+	5-1000	50/75 Ω	3.49
SCA-4-10+	5-1000	50 Ω	6.95
SCA-4-10-75+	10-1000	75 Ω	6.95
SCA-4-15-75+	10-1500	75 Ω	7.95
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• LTCC construction

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354 Rev J

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■ **Richardson Electronics**, a global distributor of RF and wireless electronic parts and components, announced today the extension of its distribution agreement with **Wavecom SA** to include North and South America. The strategic partnership will expand Richardson's distribution of Wavecom's Wireless CPU(r) products and wireless communications solutions.

■ **Kaben Wireless Silicon Inc.**, a designer of wireless semiconductors specializing in frequency synthesizers, advanced filtering and RF and mixed-signal designs, announced that it has joined the Jazz Semiconductor IP Partners program of **Jazz Semiconductor** and has been qualified as a Silicon-proven IP provider. The Application-specific IP Providers program from Jazz is intended to help its foundry customers speed time to market, reduce development risk, lower development costs and improve return on investment by qualifying semiconductor IP providers and design partners that have pre-tested and validated their methodologies for compatibility with Jazz Semiconductor.

■ **EMC Technology** and **Florida RF Labs** has appointed several new manufacturers' representatives. In the US, the partnership has added **Custom & Wireless Sales** to cover Northern California. Internationally, they have added **Hi-Tech RF & Microwave Solutions** to cover the Netherlands, Belgium and Luxembourg; **YE International** to cover Russia and the Baltic States; **LKC Oy** to cover Finland; and **Consulting Conexion Lider** to handle Spain and Portugal. For a full list of contacts and current sales representatives, visit www.emct.com or www.rflabs.com.

■ **Sivers IMA AB**, a manufacturer of microwave sources such as ultra-wideband VCOs and FMCW microwave front ends, has added five new organizations as its sales channels. In the US: **Sertech** is its representative in Pennsylvania, Delaware and Southern New York state; **T & E Repco** in Florida; **Grant Technical Sales** in Arizona, New Mexico and El Paso County in Texas; and **Thorson West** in Northern California. **Kaytronics EXIM PVT. Ltd.** with offices in Hyderabad and Bangalore is the company's representative in India.

■ **Atlantic Microwave Ltd.**, a microwave equipment and component manufacturer, is addressing developing markets in the Pacific Rim and Australia regions with the appointment of key sales representatives in Australia and South Korea. In Australia the new representative is **Stanford Technologies Ltd.**, 737 Burwood Road Hawthorn, Victoria 3122 Australia, Tel: +61 (0) 3 8862 6336, Fax: +61 (0) 3 9804 0202, e-mail: grant@stanford.net.au. In Korea, the new representative is **Phoas Co. Ltd.**, Room 1002, Anyang K-center, 1591-9, Burim-dong, Dongan-gu, Anyang-si, Gyeonggi-do, Korea 431-815, Tel: +82 31 384 1094, Fax: +82 31 384 2177, e-mail: phoas@chol.com.

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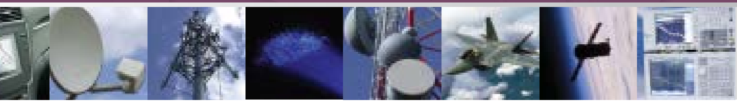

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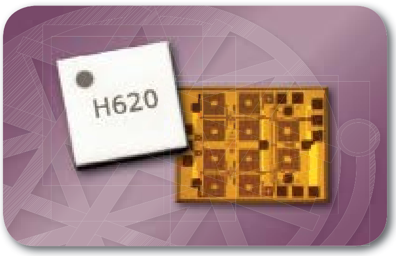

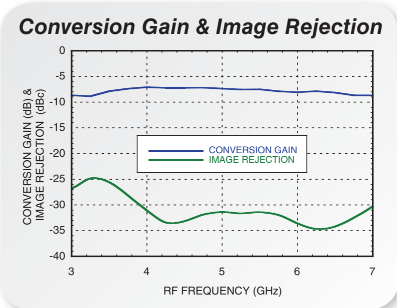

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	4 - 8.5	I/Q Mixer / IRM	DC - 3.5	-7.5	40	23	LC4	**HMC525LC4**
	5.9 - 12.0	I/Q Mixer / IRM	DC - 1.5	-8	30	18	Chip	**HMC256**
	6 - 10	I/Q Mixer / IRM	DC - 3.5	-7	40	23	LC4	**HMC520LC4**
	6 - 10	I/Q Mixer / IRM	DC - 3.5	-7.5	40	28	LC4	**HMC526LC4**
	8.5 - 13.5	I/Q Mixer / IRM	DC - 2	-7.5	34	28	LC4	**HMC527LC4**
	8.5 - 13.6	I/Q Mixer / IRM	DC - 3.5	-7.5	38	24	LC4	**HMC521LC4**
	11 - 16	I/Q Mixer / IRM	DC - 3.5	-7.5	35	24	LC4	**HMC522LC4**
	11 - 16	I/Q Mixer / IRM	DC - 3.5	-8	35	26	LC4	**HMC528LC4**
	15 - 23	I/Q Mixer / IRM	DC - 3.5	-8	25	25	LC4	**HMC523LC4**
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	22 - 32	I/Q Mixer / IRM	DC - 4.5	-10	20	20	LC3B	**HMC524LC3B**
	31 - 38	I/Q Mixer / IRM	DC - 3.5	-10.5	17	21	Chip	**HMC555**
NEW!	35 - 45	I/Q Mixer / IRM	DC - 5	-8	25	17	Chip	**HMC-MDB171**
	36 - 41	I/Q Mixer / IRM	DC - 3.5	-11	18	23	Chip	**HMC556**
NEW!	55 - 64	I/Q Mixer / IRM	DC - 3	-9	30	16	Chip	**HMC-MDB207**
	26 - 33	Sub-Harmonic I/Q Mixer / IRM	DC - 3	-11	22	16	Chip	**HMC404**
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ELECTROMAGNETIC SIMULATION OF MOBILE PHONE ANTENNA PERFORMANCE

The telecommunications sector is making great advances aimed at delivering an even stream of high-tech devices, covering the significant consumer demands in this sector. Electromagnetic (EM) simulation is becoming an increasingly important tool in the design flow, not only at the antenna level but also at the phone and environmental levels. This article compares simulated results with measurements for several steps in the phone design chain.

Today's handsets have to meet tough technical requirements. Mobile phones have to deal with an ever-increasing number of services, while at the same time the cost of the systems is being reduced. R&D in the mobile phone industry copes with this situation by continuously improving the mobile phone efficiency in order to accommodate service enhancements in the mobile network. Thus, we are moving towards mobile designs that are not only becoming thinner, smaller and more complex with every generation, but also have to perform with the same or even better performance, and in more frequency bands.

In addition to maximizing the antenna-accepted power of the handsets, the effects on the antenna performance from surrounding objects such as the human body have to be studied and considered. Homogeneous models are used when measuring the effects on antenna performance and represent a conservative estimation of antenna losses and dissipated power. The performance of the antenna and the entire system may be quantified using sets of technical requirements for both passive and active modes.

In passive mode, the antenna performance is often measured by the antenna efficiency, which is subdivided into the radiation efficiency and the return-loss efficiency. In active

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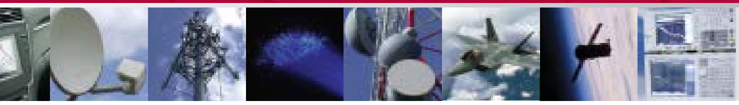

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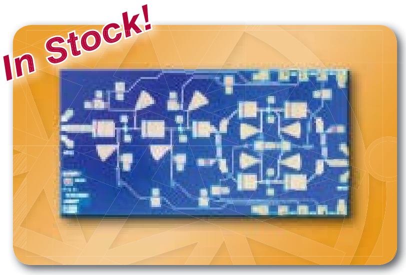

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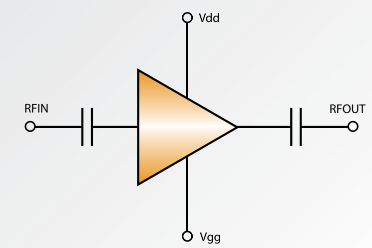

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NEW!	5 - 20	Low Noise	13	2.2	16	+5V @ 30mA	ALH435	HMC-ALH435
NEW!	14 - 27	Low Noise	18	2.5	14	+4V @ 90mA	ALH216	HMC-ALH216
NEW!	14 - 27	Low Noise	20	2	14	+4V @ 90mA	ALH476	HMC-ALH476
NEW!	18 - 40	Low Noise	10	3.9	12	+5V @ 45mA	ALH445	HMC-ALH445
NEW!	22 - 26.5	Low Noise	25	3	12	+2.5V @ 52mA	ALH311	HMC-ALH311
NEW!	24 - 32	Low Noise	21	2	7	+5V @ 68mA	ALH364	HMC-ALH364
NEW!	24 - 40	Low Noise	11.5	4	15	+4V @ 60mA	ALH140	HMC-ALH140
NEW!	24 - 40	Low Noise	12	3.5	13	+4V @ 45mA	ALH244	HMC-ALH244
NEW!	24 - 40	Low Noise	22	2	11	+5V @ 66mA	ALH369	HMC-ALH369
NEW!	27 - 33	Low Noise	20	3	12	+2.5V @ 52mA	ALH313	HMC-ALH313
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NEW!	57 - 65	Low Noise	21	4	12	+2.5V @ 64mA	ALH382	HMC-ALH382
NEW!	71 - 86	Low Noise	14	4.5	7	+2.4V @ 30mA	ALH459	HMC-ALH459
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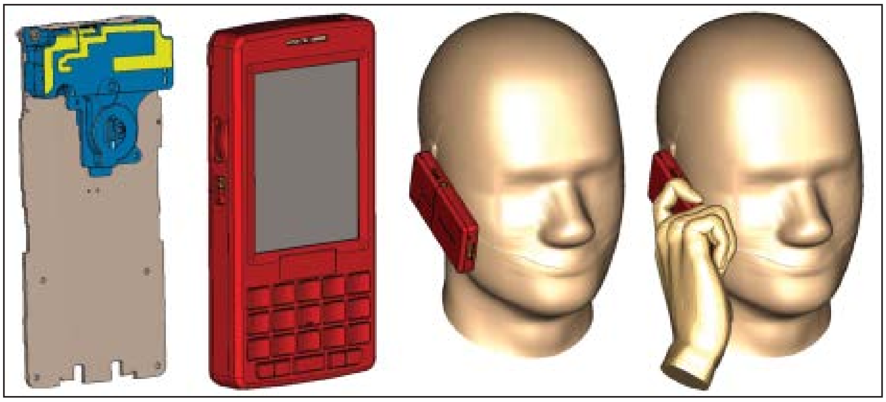

Fig. 1 *Analysis phases of the mobile phone study.*

TABLE I

CONVERGENCE STUDY FOR THE ANTENNA LEVEL CASE IN FIGURE 1

	Run 1	Run 2	Run 3
No. of mesh-cells	221,610	383,160	660,539
Simulation time (s)	450	690	1130
Max. difference	–	0.067	0.014
Radiation efficiency 1 GHz	0.894	0.901	0.906
Radiation efficiency 2 GHz	0.908	0.924	0.923

mode, the entire system efficiency is defined by the total radiated power (TRP) on transmitting (Tx), and the total isotropic sensitivity (TIS) on receiving (Rx). The active performance of the handset is often measured using exact and time-consuming procedures. These have to be conducted several times during the development phase of the device. Furthermore, the product has to be developed to a certain stage before any measurement or reliable prediction of antenna performance is possible.

Numerical simulation of terminal antennas has been actively discussed in literature. There has been considerable development in both hardware and software recently and it is important to continuously update the field with the latest developments. This article considers the accuracy of calculation of mobile phone models by comparing these calculations with measurements. The models used are taken from the recently released Sony Ericsson M600 mobile phone[1] and measurements were conducted at Sony Ericsson's test facilities. The emphasis is on the accuracy of calculations using the present state-of-the-art.

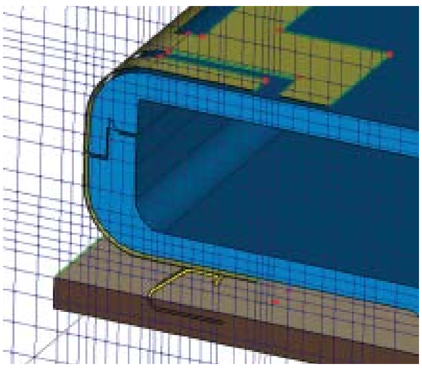

Fig. 2 *The converged mesh for the antenna simulation.*

SIMULATION TECHNOLOGY

For all simulations, the 3D EM tool CST MICROWAVE STUDIO® (CST MWS),[2] based on the finite integration technique (FIT),[3] was used. This method represents a consistent transformation of the analytical Maxwell equations into a set of matrix equations, the Maxwell Grid Equations (MGE). Thereby, essential physical properties of the analytical equations, such as energy conservation and passivity, are maintained in discrete space.[4] The MGEs can be solved by various techniques, from statics to the optical regime, in the time and frequency domains.

In the microwave range, the frequency domain approach is very flexible in the choice of discretization (tetrahedral or Cartesian meshes may be used), but it requires the solution of a large linear system of equations for each frequency step. The time domain solver, in contrast, if used on a Cartesian mesh, only requires matrix vector multiplications and therefore scales linearly with the number of mesh cells, both in terms of memory requirements and in simulation time. This offers an advantage for complex simulation models such as mobile phones; however, traditional time domain methods like FDTD can exhibit poor convergence properties.

Within the frame of FIT, advanced meshing techniques such as the Perfect Boundary Approximation (PBA)® and Thin Sheet Techniques (TST)™ can be implemented. Still based on a Cartesian mesh, the geometry is described conformally, but all the advantages of a time-domain approach, like memory efficiency and broadband results, are maintained. To improve the efficiency of certain simulations even further, a stable multi-level sub-gridding scheme can be implemented.

In order to calculate radiation efficiency correctly, it is important to model the skin depth of lossy metal accurately. FIT can be extended to consider the frequency dependency for permeability, permittivity and conductivity in one broadband simulation. Taking dispersion into account is especially important when modeling tissue-simulating materials.

ANALYZED STRUCTURES

The EM simulations conducted on the M600 mobile phone was done on several system complexity levels. These are shown in ***Figure 1***, from left to right with the least complex structures, such as the simple antenna design and PCB, to the complete phone structure containing several hundred components and finally the entire system using the head of the Standard Anthropomorphic Model (SAM),[5,6] a homogeneous hand model and the full phone.

In real mobile phones, many objects in the vicinity of the antenna element have to be considered because of their effect on the performance of the system. Therefore, great care must be taken when selecting and setting the correct simulation parameters for the relevant objects.

The analysis of antenna performance in the vicinity of bodies often comprises assumptions and simplifications. In general, homogeneous bodies are utilized in order to measure the most conservative behavior

of the system. Because of this, homogeneous head and hand models are used for simulations as well. Throughout this work, the antenna effects were quantified by calculating input impedance and antenna efficiency.

SIMULATION AT ANTENNA LEVEL

At the antenna level, the design and optimization of the antenna itself is the prime goal. Results of interest are typically the return loss, radiation efficiency and radiation pattern of the antenna at various frequencies. Even though the transient solver is used for the simulations, frequency quantities like near and far fields can be evaluated easily at numerous frequencies during one transient run due to field monitors based on discrete Fourier transforms (DFT). Realistic loss values were chosen for both the metallic and dielectric objects.

A convergence study indicates that the model converges to an accurate solution. Starting with a relatively coarse mesh of 221,000 mesh cells, and refining it using an energy-based criterion, the final solution is achieved in only three steps. The criterion for stopping the study is that the maximum difference of an S-parameter between two runs is less then 0.02 over the complete band (0 to 3 GHz). Additionally, the convergence of the radiation efficiency at the two bands was evaluated.

The total convergence took 38 minutes. For further simulations and structure optimizations, the third run can be skipped, as the mesh setup in the second run with around 383,000 mesh cells delivers well converged results. This means that all further simulations in the optimization process will have a run time of only 12 minutes. Details including individual simulation times can be taken from ***Table 1***.

The converged mesh is shown in ***Figure 2***. The bent planar parts of the PIFA antenna, the antenna carrier and the PCB can be seen clearly. As the bendings are not aligned with the Cartesian mesh, this would cause significant problems in simple staircase methods; however, due to the thin sheet technique, mesh cells can

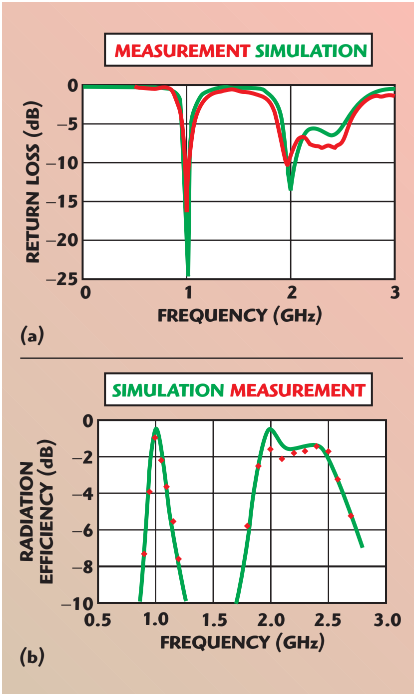

Fig. 3 Simulation vs. measurement at the antenna level; (a) return loss and (b) antenna efficiency.

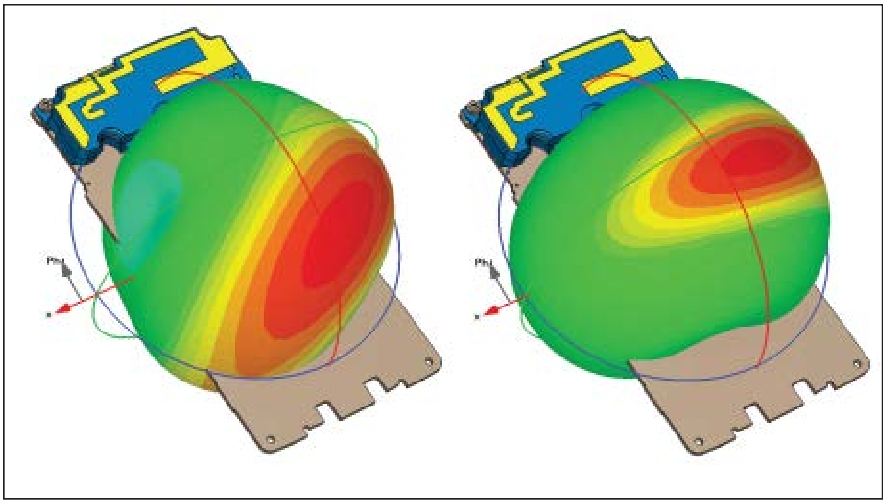

Fig. 4 The radiation pattern of an antenna for two GSM bands.

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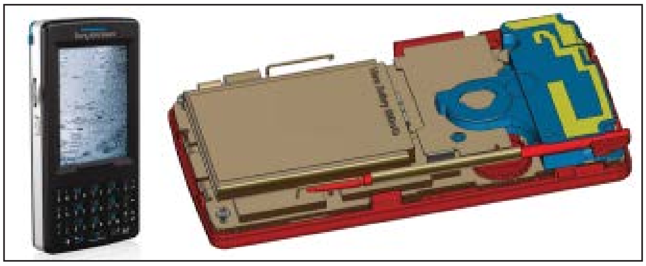
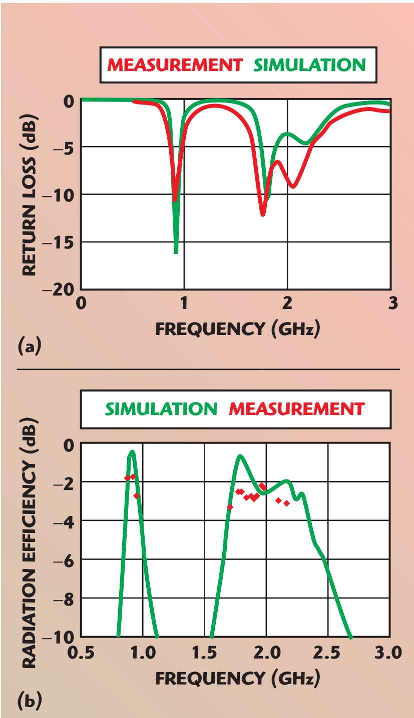


▲ *Fig. 5 Full phone model containing phone plastics (red and blue) and metallic parts (copper and gold).*

be intersected by metallic sheets. Together with the PBA technique, the shown grid, although it might look relatively coarse, delivers fully converged results.

The converged simulation results of the antenna compared with measurements are shown in ***Figure 3***. The results are in agreement for both the return loss and the radiation efficiency. Finally, the radiation pattern is shown in ***Figure 4*** for two GSM frequencies. Since the plastic housing is not considered for this study, the resonances are slightly shifted to ~1 and ~2 GHz.



▲ *Fig. 6 Comparison of simulation and measurement for the full phone simulation; (a) return loss and (b) antenna efficiency.*

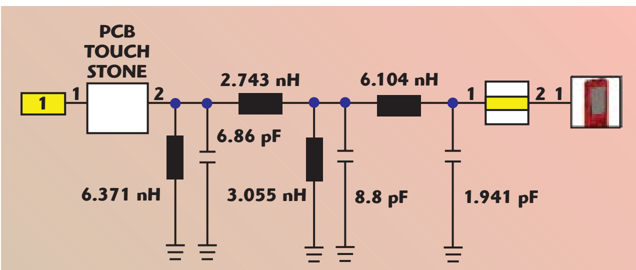
SIMULATION AT PHONE LEVEL

After the antenna design is complete, the next step is to include it in the complete phone. This enables the evaluation of the coupling effects of neighboring objects such as the battery, camera, flash capacitors, etc., as well as the influence of dielectric materials such as the housing and display screen.

The phone is subdivided into roughly 60 components, each consisting of hundreds or even thousands of individual facets(see ***Figure 5***—the back cover and battery lid are hidden for the picture). The components used for the simulation are chosen based on their influence on electromagnetic fields (which is controlled by both dimensions and location), in order to give an accurate simplification of the phone geometry for the investigated frequencies.

The structure was imported into CST MWS using the STEP interface. No additional healing was necessary before conducting the simulations, which is an important pre-requisite for efficient industrial design and workflow. The simulation of the full mobile phone consisted of 594,000 mesh cells (again after a convergence study as described in the previous section). The total simulation for the converged model took 19 minutes.

The simulation of the return loss and radiation efficiency of the full phone is compared with measurements in ***Figure 6***. As the complete phone is now considered, the frequencies are shifted down to the well-known mobile phone bands. The results again agree well with respect to resonance frequen-



▲ *Fig. 7 Network simulation including matching network and the 3D results of the antenna.*

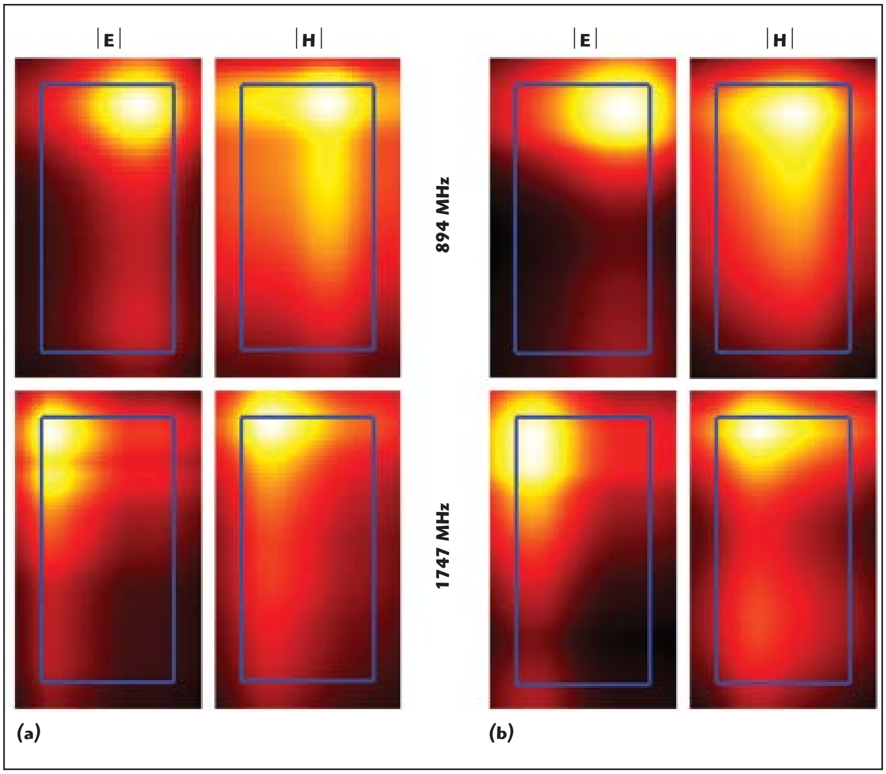


Fig. 8 Electric and magnetic near fields on the back of the phone; (a) simulation and (b) measurement.

cies, bandwidths and radiation efficiency, but some differences occur in the return loss for the upper frequencies.

These can be explained by the uncertainty regarding the antenna's exact feeding point during measurement and measurement de-embedding. Additionally, the properties of the various materials used in the phone model may be inexact.

Alongside radiation efficiency and return loss, global quantities such as the TRP and the TIS are relevant for the simulation of the complete phone. These values require the consideration not only of the antenna characteristics but also the amplifier, the signal transmission inside the printed circuit board and the matching network. ***Figure 7*** shows the simplified setup of such a circuit in CST DESIGN STUDIO™ (CST DS) including an idealized source, touchstone file describing the PCB transmission, matching network and a microstripline to feed the antenna. The simulation delivers system S-parameters, system near and far fields, and from these, the TRP value. The TRP value of this idealized setup gives 23.27 dBm at 1.8 GHz and amplifier power of 0.25 W.

The near field is also of significance for the complete phone, as interaction with other electromagnetic devices such as hearing aids (hearing aid compatibility, HAC) might occur. Near-field information can be predicted accurately by means of simulation. ***Figure 8*** compares the normalized E and H near fields at a distance of 10 mm from the back of the phone in a free space configuration. The blue outline represents the position of the phone. (Measurements were performed by Ericsson Research, Stockholm, Sweden.)

SIMULATION AT BODY LEVEL

A final test for the mobile phone is to evaluate it in the presence of a human body, with particular emphasis on the head and hand. In accordance with IEC and IEEE standards,[5,6] the Standard Anthropomorphic Model is used as the head model. The frequency dependent dielectric properties of the tissue simulating liquid are also defined by this standard and can be modeled as a dispersive material in the simulation tool. ***Figure 9*** shows the required values tabulated and realized in the simulation tool.

The simulation of this phone, with head and hand models, required 4.24

million mesh cells and had a simulation run time of 1.58 hours on a PC (dual core dual CPU, 2 GHz, 8 GB RAM). The number of mesh cells can be reduced using the sub-gridding scheme. When applied, a very fine mesh is created inside the phone, a coarser one in the head and a very basic one in the vacuum (see ***Figure 10***). Using sub-gridding reduces the number of mesh cells to only 922,000 and the simulation time to 44 minutes.

If the simulation is started without sub-gridding on a hardware acceleration card, the simulation time can be reduced even further to only 27 minutes. Excluding the meshing time, the solver speed-up using sub-gridding is 3.6. With the accelerator card, a speed-up factor of 5.8 can be achieved compared to a non-accelerated workstation.

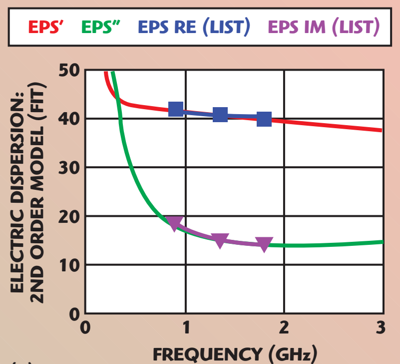
Such a simulation can give important insight into how the SAM phantom or the homogeneous body models affect the performance of the mobile phone. The radiation pattern is obviously affected, but the radiation efficiency is also influenced by the head and hand. ***Figure 11*** shows the radiation pattern of the phone; a significant difference is visible in comparison to the plain antenna far fields from Figure 4.

As previously mentioned, the radiation efficiency is influenced by the body models. ***Table 2*** shows the antenna efficiency calculations for only the phone, the phone placed at the right cheek of SAM and the phone held at SAM's right cheek with a hand model present.

Finally, full-SAM simulations are very useful to predict dissipated power. This quantity—as a measured value—is another important design is-

FREQUENCY (MHz)	ε_r	σ (S/m)
835	41.5	0.90
900	41.5	0.97
1800-2000	40.0	1.40

(a)



(b)

Fig. 9 Tabulated values for the tissue properties by IEEE 1528 (a) and the broadband material fit used by CST MWS (b).

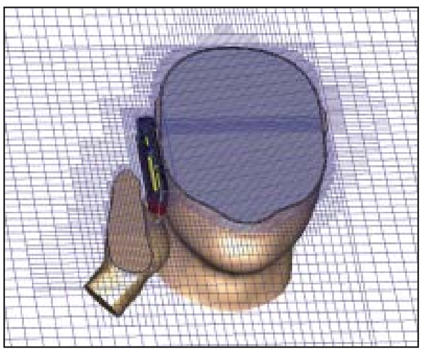
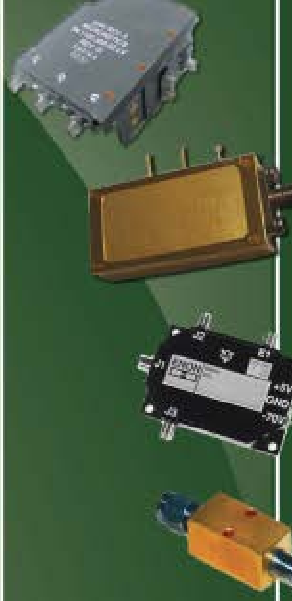


Fig. 10 Sub-grid setup for a mobile phone simulation in the presence of head and hand.

High Performance Radar Components

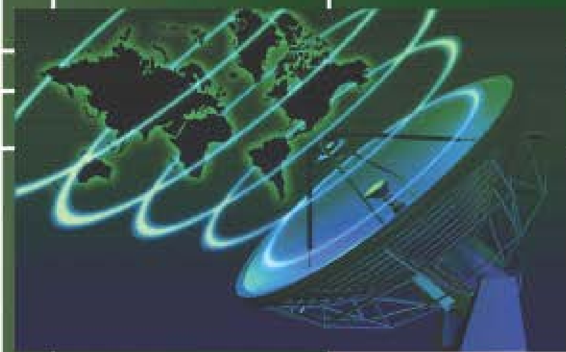


X-Band switching assemblies

High ENR broadband noise sources 1 - 18 GHz

High power X, Ku band 300W switches

High power X-band 1000W power limiters



Micronetics has been manufacturing an extensive line of RF/ microwave components and subassemblies suited for military and commercial radar applications for over 30 years.

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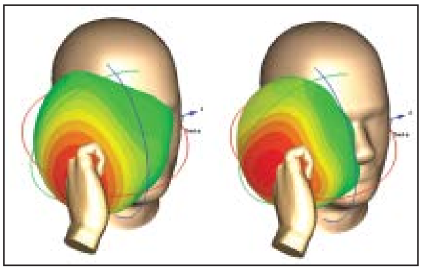

▲ *Fig. 11 The modified radiation pattern for the two GSM bands in the presence of head and hand.*

TABLE II

ANTENNA EFFICIENCY CALCULATIONS

Frequency	897.4 MHz	1747.6 MHz
Phone	100%	100%
Phone head	23% (–6.3 dB)	48% (–3.2 dB)
Phone head hand	6% (–12.2 dB)	7% (–11.5 dB)

sue and a requirement for certification. However, a simulation allows the designer to control this power at a much earlier design stage.

CONCLUSION

This article has shown what is currently possible in the world of advanced 3D EM simulation. Throughout all steps of a mobile phone's terminal antenna development—from antenna design, through full phone optimization up to investigating the influence of, and impact on a body model—simulation and measurement have been compared and shown to be in very good agreement. In addition to measurable data, numerical simulation grants insight into previously unseen electromagnetic detail.

Within one simulation run, all-important quantities such as return loss, radiation efficiency, near and far fields, and loss monitors (all at various frequencies) can be obtained. Advanced mesh technology significantly reduces the simulation time, bringing it down to a few minutes for an antenna simulation. Even complex automatic optimization runs become feasible. The increasing efficiency and reliability of simulation, which reduces design cost risk, is recognized as indispensable in the industry. ■

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DESIGN ENABLEMENT FOR RF AND MICROWAVE IC DESIGN: PART II

Editor's note: *This two-part series from Jazz Semiconductor presents recent developments in design-support methodology from a pure-play wafer foundry specializing in RFCMOS and advanced CMOS technologies, including BiCMOS, SiGe BiCMOS and high voltage CMOS. In this second part of the series, the authors present CMOS manufacturing technology as it is being adapted for the challenges associated with producing high-yielding ICs with sensitive RF blocks. The models and methodologies of the design-enablement tool introduced in Part I are combined with statistical corner models and design-for-manufacture (DFM-driven) methodologies to address the extremes of process variations.*

Variations in semiconductor manufacturing technology are unavoidable; therefore, the IC must be designed for yield even at the extremes of process variation. The goal of statistical and corner models is accurate simulation of the process-induced variation of circuit performances, such as gain-bandwidth products, distortion levels and phase noise. Process control monitoring (PCM), performed on every wafer produced by a fab, measures the process variation of device-level electrical performances (I_{dsat}, beta), referred to here as **e**. The statistical infrastructure called backward propagation of variance (BPV)[1] produces statistical models that guarantee precise simulation of the variation of **e** and achieve the goal through the physical nature of the compact models. Therefore, a direct BPV requirement is scalable, physical compact models that accurately simulate the physical sensitivities of **e** to variations in process and geometry model parameters, termed **p**.

Figure 1 shows the mathematical representation of BPV in action for the PSP model. The variances of **e** are input directly from the PCM. The PSP sensitivity matrix is calculated directly within the circuit simulator. The system determines the variances of **p** ($\sigma^2_{\delta p}$), which guarantees alignment of the simulated and measured variances of **e**. The 1–σ values of **p** are then input to the Monte Carlo statistical simulation tool within the design environment or scaled to produce corner models. The results are accurate in most cases to < 0.5 percent. This technique is employed across all device types, utilizing all the available PCM. In addition to accurate simulation of individual **e**, physical correlations among

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Newport Beach, CA

$$\sigma^2_{\delta ei} = \sum_k \left(\frac{\partial ei}{\partial pk}\right)^2 \sigma^2_{\delta pk}$$

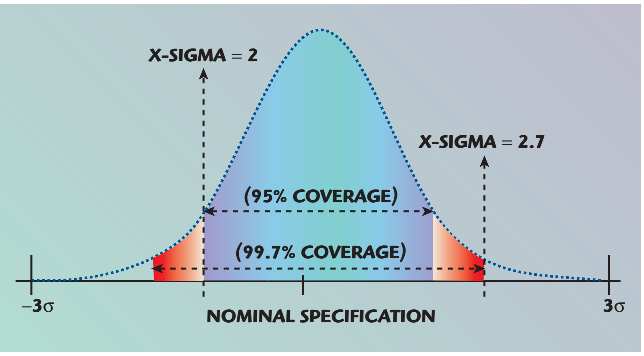
VARIANCES OF PCM (e) — MODEL SENSITIVITIES — VARIANCES OF PROCESS MODEL PARAMETERS (p)

$$\begin{bmatrix} \sigma^2_{\delta Vtl} - \left(T_{ox}\frac{\partial V_{tl}}{\partial T_{ox}}\right)^2 \frac{\sigma^2_{\delta Tox}}{T_{ox}} \\ \sigma^2_{\delta Idl} - \left(T_{ox}\frac{\partial I_{dl}}{\partial T_{ox}}\right)^2 \frac{\sigma^2_{\delta Tox}}{T_{ox}} \\ \sigma^2_{\delta Vts} - \left(T_{ox}\frac{\partial V_{ts}}{\partial T_{ox}}\right)^2 \frac{\sigma^2_{\delta Tox}}{T_{ox}} \\ \sigma^2_{\delta Ids} - \left(T_{ox}\frac{\partial I_{ds}}{\partial T_{ox}}\right)^2 \frac{\sigma^2_{\delta Tox}}{T_{ox}} \end{bmatrix} = \begin{bmatrix} \left(\frac{\partial V_{tl}}{\partial V_{fb}}\right)^2 & \left(\frac{\partial V_{tl}}{\partial \mu_0}\right)^2 & \left(\frac{\partial V_{tl}}{\partial DV_{tl}}\right)^2 & \left(\frac{\partial V_{tl}}{\partial \Delta L}\right)^2 \\ \left(\frac{\partial I_{dl}}{\partial V_{fb}}\right)^2 & \left(\frac{\partial I_{dl}}{\partial \mu_0}\right)^2 & \left(\frac{\partial I_{dl}}{\partial DV_{tl}}\right)^2 & \left(\frac{\partial I_{dl}}{\partial \Delta L}\right)^2 \\ \left(\frac{\partial V_{ts}}{\partial V_{fb}}\right)^2 & \left(\frac{\partial V_{ts}}{\partial V_{fb}}\right)^2 & \left(\frac{\partial V_{ts}}{\partial DV_{tl}}\right)^2 & \left(\frac{\partial V_{ts}}{\partial \Delta L}\right)^2 \\ \left(\frac{\partial I_{ds}}{\partial V_{fb}}\right)^2 & \left(\frac{\partial I_{ds}}{\partial \mu_0}\right)^2 & \left(\frac{\partial I_{ds}}{\partial DV_{tl}}\right)^2 & \left(\frac{\partial I_{ds}}{\partial \Delta L}\right)^2 \end{bmatrix} \times \begin{bmatrix} \sigma^2_{\delta Vfb} \\ \sigma^2_{\delta \mu 0} \\ \sigma^2_{\delta DVtl} \\ \sigma^2_{\delta \Delta L} \end{bmatrix}$$

Rows: LONG CHANNEL Vth; LONG CHANNEL ID; SHORT CHANNEL Vth; SHORT CHANNEL ID. Parameters: FLATBAND VOLTAGE; MOBILITY; SHORT CHANNEL THRESHOLD; EFFECTIVE CHANNEL LENGTH.

▲ *Fig. 1 BPV example with PSP Model.*

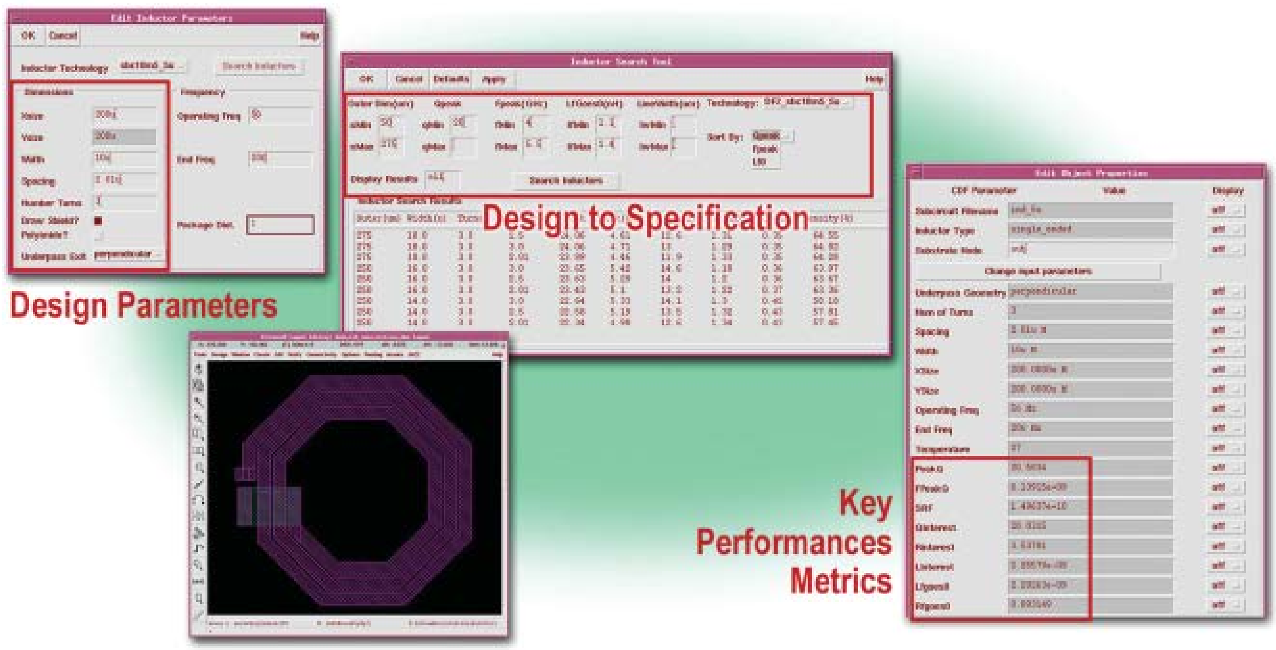
multiple e are accurately captured. The BPV infrastructure is the basis for a suite of tools embedded in the Jazz analog design environment including X-Sigma models and the Process Control Modeling Tool (PCMT).



▲ *Fig. 2 X-Sigma flexible corner example.*

X-SIGMA

As a greater amount of RF integrated circuits connect with consumer applications, the influence of "cycle time to functional silicon" on market penetration and ultimate product success is on par with—and in some cases exceeds—overall cost or performance. In many cases, front-end design consumes the bulk of the design cycle. While completing a design that meets specification for nominal process cases can be quick, the larger portion of budgeted cycle time is spent improving design robustness so target specifications are met across process variation. To allow for efficient process variation exploration, the proposed design flow offers designers a tool to help them understand how effectively the IC meets design targets across such variations. As motivation, take the example of a designer's goal to meet specification targets across ±3σ process corners. ±3σ represents 99.7 percent of statistically expected process variation, which is close to ideal yield.



▲ *Fig. 3 JIT inductor design example.*

As an example, it may require three design team weeks to achieve 95 percent (or ±2σ) spec coverage, but an additional eight weeks to reach ±3σ coverage. In consideration of time to market, the design team may want to trade off design cycle for a small percentage of corner compliance. Typical foundries provide hard coded ±3σ corner models, restricting information concerning the design's location within the 3σ process variation space. The Jazz X-Sigma corner platform provides process sigmas as variable inputs that can be swept in an analog manner across the process variation spectrum. The added flexibility provides direct insight into circuit sensitivities across the process variation space previously hidden by the fixed corner settings. Through X-Sigma, the example design team may determine what coverage—and hence, expected parametric yield—a design will enjoy at any point in the design cycle. ***Figure 2*** illustrates a sample X-Sigma corner-selection process for a given specification distribution.

PHYSICAL DESIGN ENABLEMENT

The increase in carrier frequencies in microwave applications has made possible the cost-effective integration of active and passive microwave elements into a single substrate. In previous generations, the cost associated with introducing microwave compliant layouts into ICs was unreasonable because the performances (for example, inductance and impedance) resulted in prohibitive geometries. To illustrate, a quarter-wave transformer built on a microstrip for a 900 MHz spread spectrum application will be 70 times longer than its parallel for a 64 GHz band application such as collision avoidance. In modern technologies, it is now possible to integrate these high-value functionalities in a cost-effective manner. For active circuitry, the improvement in process technologies through scaling has also paved the way for ICs to reach performance previously only possible through higher-cost discrete systems. In order to manage the risk of introducing layout topologies with inherent microwave deficiencies, the physical design libraries include parameterized layout cells (pcells) with embedded process technology knowledge and best practices. Moreover, the physical views are robustly tied into the simulation environment in the same manner as the device models, enabling design performance optimization.

RF MOSFET

The role of the CMOS transistor as an RF capable device continues to expand across the industry. In order to obtain the required performance metrics, their physical implementation must be tailored to achieve maximum RF performance. Two key device parasitics to be minimized are gate and substrate resistance. Gate resistance is a critical component of device noise performance and its subsequent mapping to phase noise, linearity, etc. Minimizing these negative effects is possible through proper gate connectivity layout configurations. The design platform should include RF pcells allowing multiple FET gate configurations, driving down the total noise generating resistance intrinsic to the gate.[9] At RF frequencies, the core device interacts with the lossy silicon substrate, directly reducing the output impedance. This interaction is heavily dependent on how the bulk ties are distributed around the device. In RF CMOS layout, bulk contacts closely wrapped around the device produce the smallest deviation from ideal behavior. The pcell should therefore also contain multiple substrate tie options, including a ring that significantly reduces the “rollup” in drain-source conductance g_{ds} at high frequencies. It is important to offer a parameterized cell that can draw these optimized contacts, but just as importantly drive the models that accurately capture the element configuration.

NPN

Bipolar devices, including high-performance silicon germanium NPNs, are common in high-performance RF applications due to their superior gain, noise, isolation and power metrics. Bipolar layout style strongly influences device performance; for this reason an RF focused parameterized NPN cell that yields high emitter area and low parasitic resistance and capacitance is requisite. As the cornerstone of the optimized NPN pcell, the emitter length should be offered as a fully scalable parameter. This feature, available in the Jazz

WHITEPAPER

Agilent Technologies

ADS Connected Solutions

The process for developing advanced Radar and EW systems often begins with component design and system simulation using software tools, which is followed by prototyping the design and evaluation using test instrumentation. In the past, there has been minimal connection between the software simulations and hardware prototype evaluation because the tools required to bridge the gap between simulation and physical test did not exist. It is now possible to integrate Agilent test instrumentation, such as signal generators and analyzers, directly into the Agilent Advanced Design System (ADS) simulation environment, which results in innovative design and verification capabilities as virtual and real world signals are shared between the two domains. As an example, this paper will show the benefits of combining a simulated ADS radar model with physical test equipment to create what is referred to as a "connected solution".

Connected solutions can provide several benefits. A connected solution lets designers quickly perform simulations to evaluate component and system performance and then turn the simulated signals into real RF signals for hardware testing. Conversely, designers can take the measured output from a system or Device Under Test (DUT) and bring that signal into ADS for additional analysis. With connected solutions, a hardware component, finished before the rest of the system, can be evaluated in the context of the entire system. Figure 1 shows a simplified block diagram of one possible configuration for using the ADS software tool connected to an Agilent ESG vector signal generator and Agilent PSA spectrum analyzer. There are a variety of Agilent signal generators and analyzers that will work in a connected solution. In this figure, the ADS source model drives the simulator's transmitter, channel and receiver, and it is also used as the input to the Arbitrary Waveform Generator (AWG) in the ESG signal generator. The signal generator becomes the real world equivalent of the source used in the simulation. This "live" signal can then be transmitted or applied to the system hardware under test. Using an Agilent PSA, the measured waveform can be downloaded into ADS and processed using the detection algorithms inside the software, which facilitates comparisons between simulated and physical system performance. The connected solution is an excellent tool for designing, simulating and experimenting with a variety of radar and EW configurations including environments with co-channel and adjacent interference, multipath fading and denial of service scenarios.

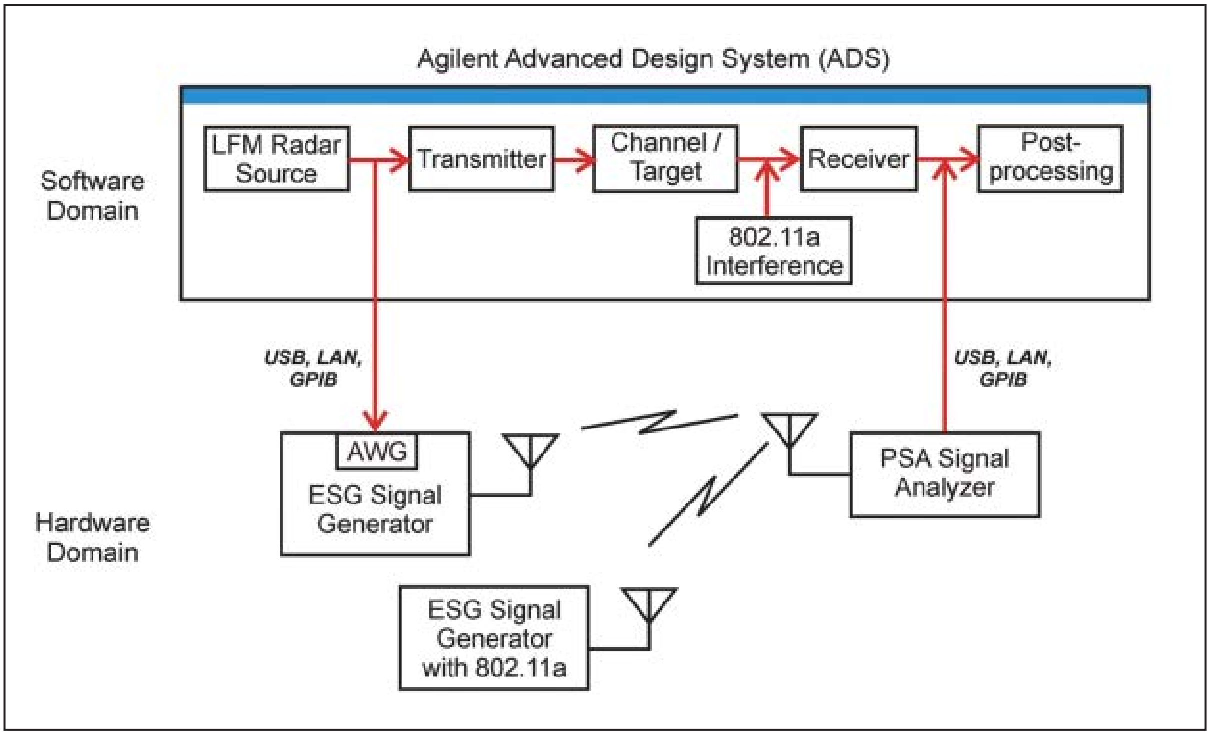


Figure 1 *Simplified block diagram of an Agilent connected solution*

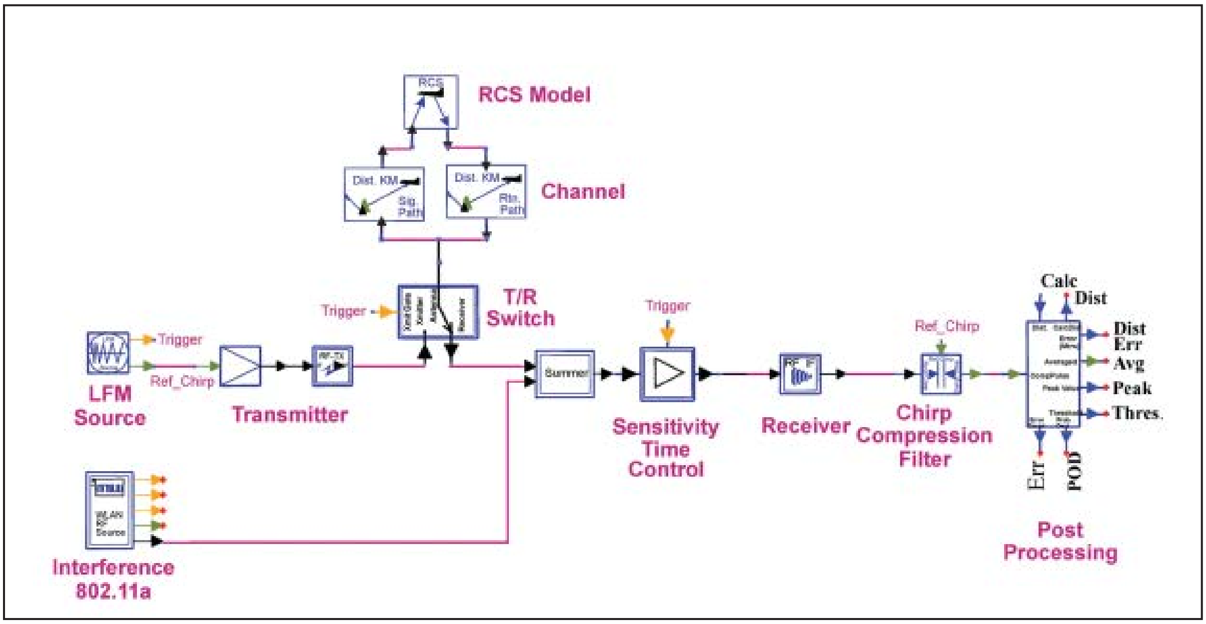


Figure 2 *ADS radar system model including 802.11a interference*

Radar System Model

The ADS software tool provides a method for creating a hierarchical model of the radar system using predefined and customizable blocks. Each block may represent a unique component, such as the Linear Frequency Modulated (LFM) signal source, or a complete subsystem such as an RF upconverter. The software model can be configured to include all the impairments of a physically implemented system such as phase noise and amplifier compression. Many commercially available simulation tools perform system analysis using a baseband equivalent model for the modulated RF signal in order to increase simulation speed. Most of these baseband equivalent simulations do not include circuit impairment effects, such as non-linearities, which result in reduced model accuracy. For the highest level of accuracy and simulation speed, the software simulation tool should use a combination of frequency and time domain simulations, simulated at RF frequencies, such as the harmonic balance and circuit envelope simulators found in Agilent's ADS software.

Figure 2 shows the ADS model for a complete C-band radar system with a single target and a single interferer. This model will be used to study the system performance when an interfering 802.11a WLAN signal is introduced into the wireless channel. The radar transmitter includes an LFM source that is upconverted, amplified and transmitted into the channel. The channel model includes antenna gain, path loss, delay and multipath. The target is modeled having a specific Radar Cross Section (RCS) and velocity. The radar receiver includes a transmit/receive switch, variable gain amplifier and downconverter. Signal detection is preformed at baseband using chirp compression. Post detection processing will be implemented to determine the target range, velocity, detection threshold, Probability of Detection (POD) and Probability of False Alarm (PFA). All of the blocks and subsystems are available as part of the ADS simulation tool.

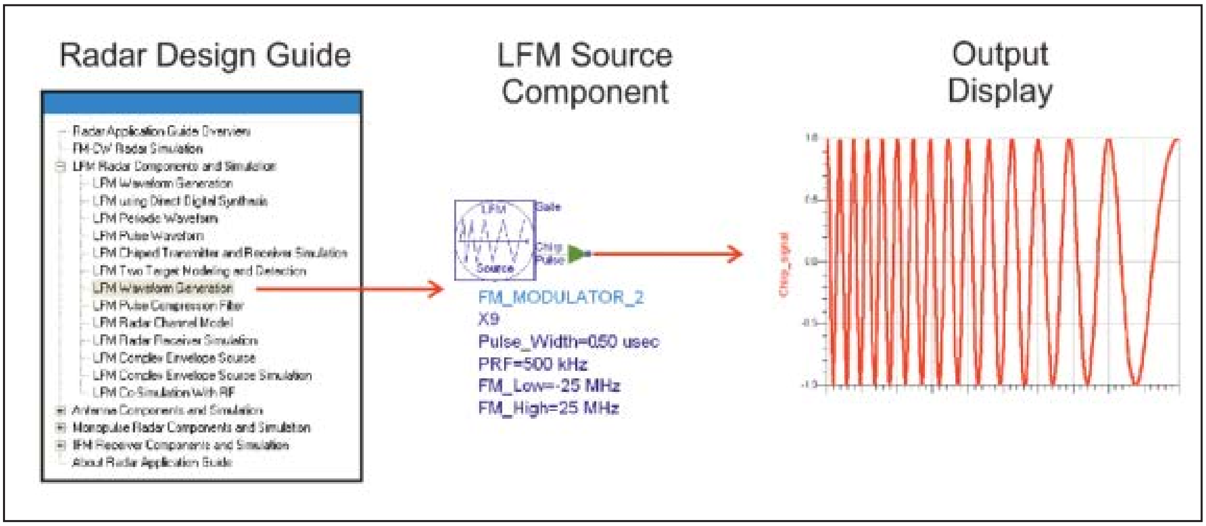


Figure 3 *LFM source model and output waveform*

LFM Signal Generation

Agilent ADS has a variety of useful built-in signal sources for simulating radar and EW systems including a model for a LFM signal using Pulse Compression. Pulse Compression enables a radar to achieve the high range resolution of a short pulse without the need for a high peak transmit power through the use of a modulated long pulse. The LFM model generates a complex pulse with configurable parameters such as pulse width, repetition frequency, chirp frequency range, and rise and fall times. The ADS component for the LFM source is shown in figure 3. This source is configured with a pulse duration of 0.5 µs, a PRF of 500 kHz and an instantaneous frequency change of +/- 25 MHz from the nominal carrier frequency. The simulated output from the LFM generator is also shown in this figure.

The LFM source is part of the Radar Applications DesignGuide within ADS. DesignGuides are collections of preconfigured simulation models that can be modified as needed [1]. Figure 3 shows a list of available LFM radar models including the LFM waveform generator used in this simulation. ADS also provides numerous other DesignGuides including a WLAN source that will be used later in this paper as a source of interference to the radar system model. Another important feature of ADS is that signal sources are not limited to those in the DesignGuide but can be created using other ADS components, using measured data from a signal analyzer, imported data from Matlab© or driven from a file possibly created by a DSP or systems engineer.

Receiver and Post Detection

Once the LFM signal is generated and transmitted toward the target, the receiver must measure and detect the presence of reflected energy from that target. The target's reflectivity is determined by its RCS and modeled using an ADS schematic component as shown in figure 2. The target return enters the receiver through a T/R switch followed by a variable gain block called the sensitivity time control. The T/R switch is used to isolate the high power transmitter from the receiver front-end. The sensitivity time control provides additional isolation when the transmitter is active and provides gain when the transmitter is off. The receive gain increases with a log function of the time, thus for a given target RCS, the signal level at the receiver front-end will remain fairly constant as distance to the target increases.

The received IF waveforms as a function of time at two different target distances are shown in figure 4. The received signal at a target distance of 1.0 km from the radar system is shown on the top. In this plot, the chirped pulse is received after the two-way trip through the channel. In this case, the pulse is received 6.7µs after the pulse is transmitted. The transmitted pulse is not observed on this plot due to the high isolation between the transmitter and receiver provided by the T/R switch and sensitivity control. The lower plot shows the received signal at a target distance of 7.0 km. In this case, the two-way trip takes 46.7µs . Note that both simulations show an increase in the noise level over time as the sensitivity control increases the receive gain as the log of the time.

After down-conversion, the IF signal passes through the chirp compression filter that performs a convolution with a reference chirp. A peak in the filter's output corresponds to the target distance measured in time. Any noise that passes through the compression filter is greatly reduced as it is uncorrelated to the reference chirp. After chirp compression, the correlated signal is further processed using a post-detection processing block as shown in figure 2 above. This block performs several calculations including the POD and missed detection count. Additional measurements such as Constant False Alarm Rate (CFAR) can also be added to the model as required. In an actual radar system the post-detection algorithms will be presented with a variety of signal impairments including interference, phase noise, compression and other real-world non-linear effects. For the simulations using the waveforms in figure 4, the probability of detection was calculated at 100% at target distance of 1.0 km with a 1.0 Meter Radar Cross Section (RCS) and around 85% at 7.0 km with a 0.2 Meter RCS. In the next section of this paper, degradation in system performance will be observed with the introduction of a WLAN interfering signal.

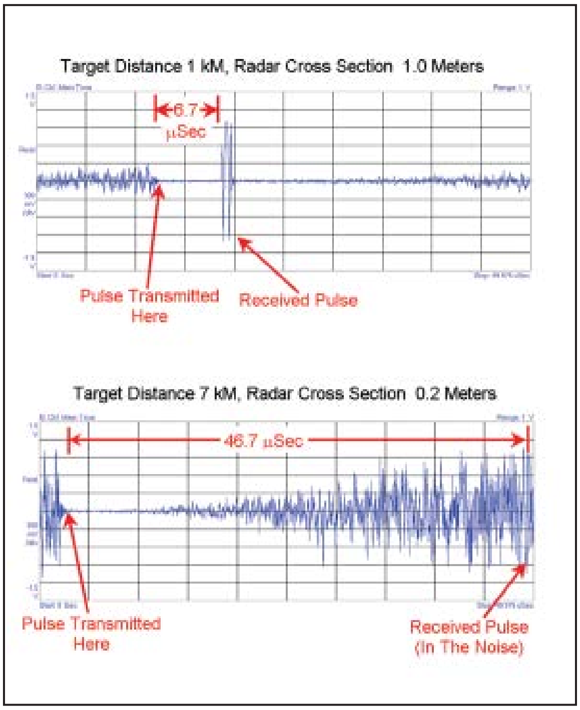


Figure 4 *Received IF waveforms for target range of 1.0 km and 7.0 km*

Radar Interference

In this section, the performance of a radar system's ability to detect weak target returns in the presence of a commercial WLAN radio will be observed. In practice, the radar and WLAN signals could potentially occupy the same frequency bands at the same time, resulting in interference and degraded performance for both systems. For this example, an IEEE 802.11a WLAN will be operating within the frequency range of the C-band radar system [2]. The radar chirp is configured with a pulse width of 0.5 µs and a PRF of 25 kHz. The WLAN packet length, as specified by the IEEE 802.11a standard, can be hundreds of microseconds depending on the packet type and modulation. Under these conditions there will be times when the radar signal and WLAN signal will collide. When these "hits" occur, the radar's signal detection capability is greatly reduced. Figure 5 shows the Probability of Detection (POD) for the radar system as a function of WLAN power. For a specified POD of 90% or greater, the received WLAN signal must be below -87 dBm. For this example, the WLAN center frequency is the same as the nominal carrier frequency of the chirp. It is also possible to simulate the results when the WLAN center frequency is offset from the radar's center frequency. Figure 5 also shows the POD when the WLAN center frequency is adjusted over the range of +/- 12 MHz. For this case, the WLAN output power is set to -82 dBm. When the two signals are lined up in frequency, which represents a worst-case condition, the POD is at 50%. As the WLAN center frequency moves away from the radar's nominal frequency, the POD rapidly improves to 100% at a 12 MHz offset.

"Connected" Signal Generation

Connecting the ADS software to an Agilent signal generator as a connected solution turns a simulated signal into a real world RF signal. As previously mentioned, ADS signals can be shared as complex inputs to a vector signal generator containing a two-channel AWG such as that found in the Agilent E4438C, E8267D and N5182A [3]. In this case, ADS connects to the signal generator via the USB, LAN or GPIB to download complex

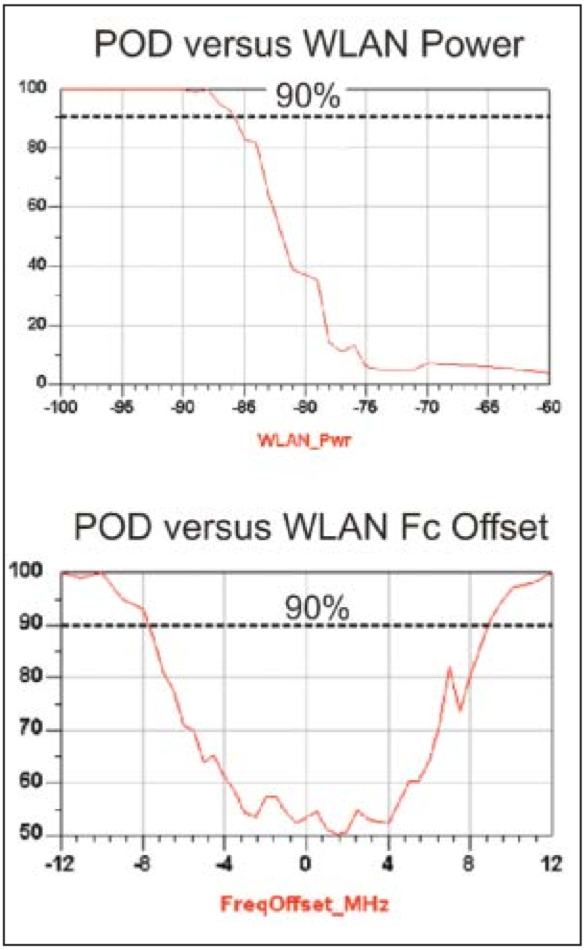


Figure 5 *Probability of detection curves with WLAN interference*

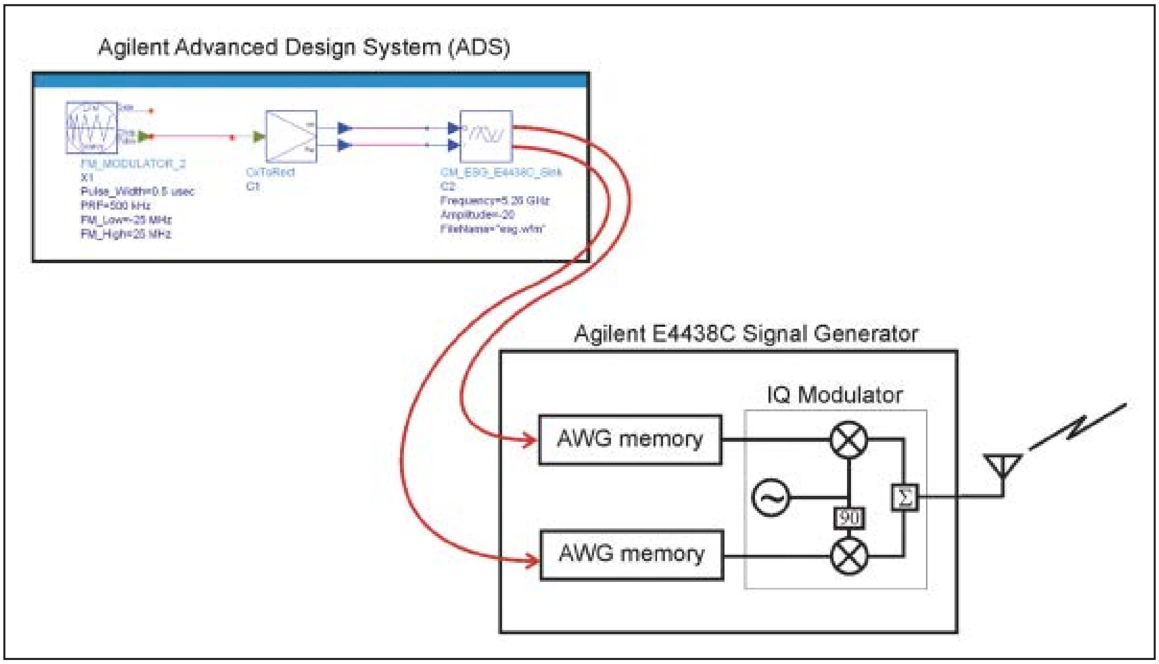


Figure 6 *ADS to Agilent E4438C ESG signal generator connected solution*

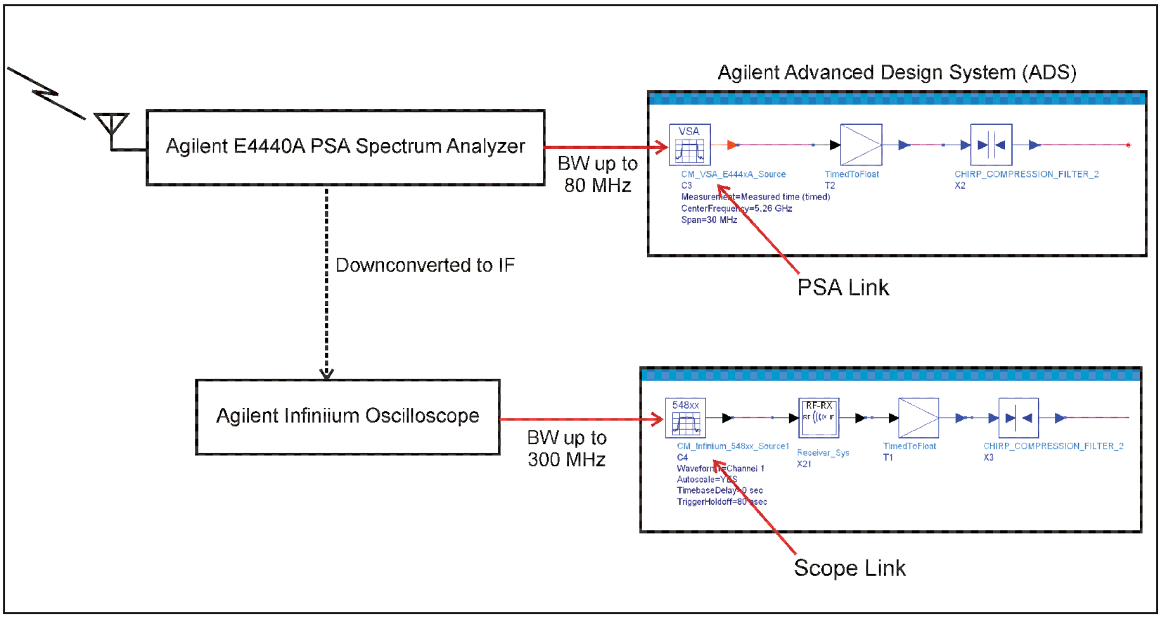


Figure 7 *ADS to Agilent E4440A PSA spectrum analyzer connected solution*

(IQ) samples of the chirp waveform into the AWG memory for playback through the signal generator. Figure 6 shows the ADS source connected to an instrument control for the Agilent E4438C signal generator. The complex LFM source is converted to I and Q data paths that are downloaded in the AWG memory in the signal generator. The signal generator uses the AWG for input to the internal IQ modulator. The modulated signal can then be applied to a DUT or transmitted into the surrounding environment with an antenna attached to the generator as shown in figure 1. Using ADS to directly control the test instrumentation greatly facilitates the process of loading waveforms into the signal generator's AWG memory. Agilent's vector signal generator family can provide predefined and custom waveform generation with carrier frequencies up to 44 GHz and modulation bandwidths of 1 GHz. The same process can be used for generating the WLAN interference, or, as will be shown in a later section, using the built-in 802.11a signal generation capability available in the Agilent E4438C signal generator.

"Connected" Signal Analysis

Once the radar pulse is applied to the DUT or transmitted over-the-air, a correlation analysis of the received chirp signal may be performed once the RF signal is captured using a signal analyzer. The connected solution shown in the upper portion of figure 7 uses an Agilent E4440A PSA series spectrum analyzer to capture the radar signal. ADS supports an instrument link to the PSA that allows direct download of the measured signal into the software. The waveform can be downloaded as frequency or time domain samples. The sampled waveform can then be processed by ADS using the same chirp compression filter. The PSA series analyzer provides signal analysis with an RF carrier frequency up to 50 GHz and bandwidths up to 80 MHz. The Agilent 89600 series VSA may also be used to capture the radar signal with RF carriers up to 6 GHz and bandwidths to 36 MHz. If wider bandwidths are required, the PSA series spectrum analyzer can be connected to an Agilent oscilloscope to achieve measurement bandwidths of 300 MHz. In this configuration, as shown in figure 7, the PSA operates as a downconverter and an Agilent Infiniium oscilloscope captures the IF waveform for download into ADS. This signal is further downconverted to baseband using ADS and then correlated with the reference chirp for post processing. As in the case for signal generation, this ADS connected solution accelerates data capture and analysis of complex waveforms between the real and virtual domains.

"Connected" Radar System with Interference

As a measurement example for a complete over-the-air radar system with interference, an Agilent ESG signal generator is connected to ADS for generation of the LFM signal. A second ESG is configured as an 802.11a interfering signal. The WLAN interference could also be created using a commercially available WLAN card, but using a signal generator with built-in WLAN personality provides greater control over the interferer's output power and center frequency. The Agilent PSA series analyzer captures the chirp and interfering signals for processing in the ADS environment. Figure 8 shows the measured signal containing both the radar chirp and the WLAN signal. In this figure, the peak amplitude for both waveforms is approximately the same but the WLAN signal overlaps several of the periodic radar pulses. During this overlap, the radar detection capability may be reduced. The equipment and software configuration for this example was previously shown in the simplified block diagram in figure 1.

Once the signal is captured using the Agilent PSA, the waveforms are connected to the ADS software for additional processing. Figure 9 shows the correlated output from the ADS chirp compression filter for measurements with and without the 802.11a interference. For the measurement without interference

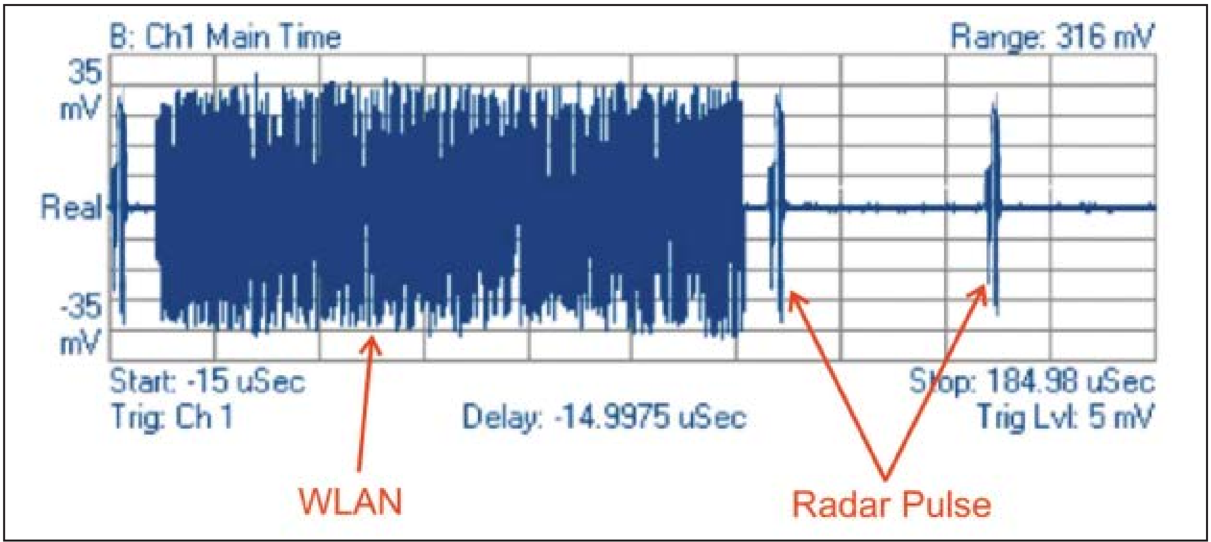


Figure 8 *Measured IF waveform including chirp and WLAN signals*

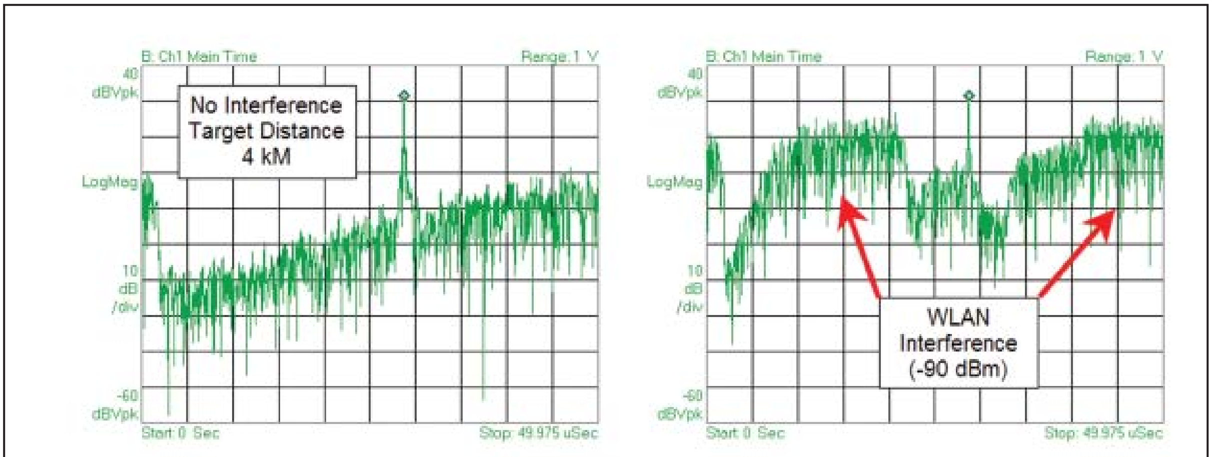


Figure 9 *ADS chirp compression filter output using measured data with and without WLAN intereference*

(shown on the left in figure 9), the correlation peak is approximately 20 dB above the filter's output noise. For the measurement with interference (on the right), the correlated peak output is only 6 dB higher than the maximum peak of the interference. Under this test condition, the radar sensitivity and range is greatly reduced with the introduction of 802.11a interference.

Conclusion

Agilent's connected solutions provide an excellent technique to bridge the gap between software modeling and hardware test. Connected solutions allow signals, algorithms, and data to be shared between the two domains thus enabling new design and verification capabilities. Additional information concerning connected solutions can be found at the Agilent website [4]. For further assistance, Agilent field representatives are trained to assist in selecting the right connected solution for those demanding aerospace and defense applications.

References:

[1] http://eesof.tm.agilent.com/products/e5600a_radar_app_guide.html

[2] "Co-interference between military radars and 802.11a WLAN networks", Leiss, David, AUTOTESTCON 2003. IEEE Systems Readiness Technology Conference. Proceedings, 22-25 Sept. 2003 Page(s):290 - 293.

[3] Agilent Application Note, Number 1394, "Connected Simulation and Test Solutions Using the Advanced Design System", Literature number 5988-6044EN, August 2002.

[4] http://eesof.tm.agilent.com/products/connected_solutions_main.html

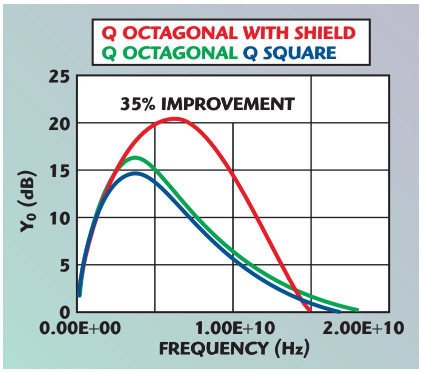
5989-7743EN January 2008

Design Enablement, allows for the definition of arbitrary emitter areas, facilitating design for gain, noise, or matching. The NPN pcells allow designers to explore different base and collector topologies for further performance optimization. Some examples of available scaling features include:

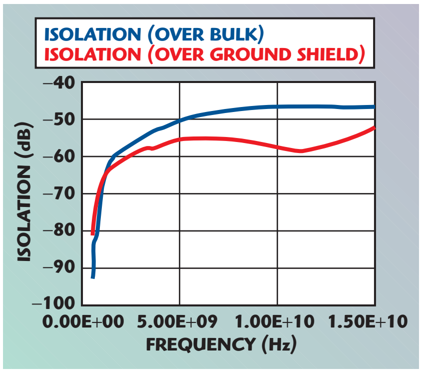
- Base configuration: choose between single or dual base contacts to trade off parasitic capacitance/footprint for base resistance
- Collector configuration: choose between single or dual collector contacts to trade off collector resistance for parasitic capacitance/footprint. RF enhanced cell uses low resistance double collector contacts for multi-emitter devices
- Emitter width configuration: choose between emitter widths to trade off between base resistances, f_T for parasitic capacitance, current consumption and matching

INDUCTOR

In electromagnetic elements, layout defines first-order device performance. The aforementioned JIT inductor toolbox provides scalable inductor and balun parameterized cells built upon electrical and process rules, metal current density limitations and process technology insight. To assist designers in selecting the appropriate passive on-chip component, an inductor library should provide designers with access to quality factor, inductance and frequency metrics prior to layout or simulations, as is the case with the JIT kit. This front-end design feature is combined with a fast-coil-optimization tool that helps designers quickly explore device geometry and electrical performance space. ***Figure 3*** shows a sample inductor design flow using JIT.



▲ *Fig. 4 Q for different inductor geometries.*



▲ *Fig. 5 Inductor substrate coupling isolation analysis: shielded vs. unshielded.*

In all cases, these validated cells maximize performance without introducing costly modules, such as RDL layers or post processing. ***Figure 4*** shows the Q performance comparison of square, octagonal and shielded octagonal geometries. ***Figure 5*** illustrates the improved inductor isolation of a device over ground shield vs. a device over standard substrate.

Additional design flow features must include critical design rule requirements to safeguard modeled EM performance. For instance, cell integration prohibits running a symmetric inductor center tab through the core of the inductor as it would increase AC resistance and degrade Q. Another design rule may restrict the addition of dummy metal fill around the device, which would adversely affect performance. A smart library like JIT can enforce these restrictions or lift them for nanometer scale technologies where metal fill is required within inductors to meet manufacturing requirements.

DFM LOOP CLOSURE TOOLS

Statistical Loop Closure (SLC)

Successful RF analog design hinges on synergy between models and fab. Statistical-process-control tools such as C_p and C_{pk} measure precision and quality of the PCM data. Many PCM parameters vary independently, leading to straightforward mapping and verification of models, fab disposition limits and actual PCM data through C_p/C_{pk} targets. However, as previously described, many PCM parameters are derived from shared device and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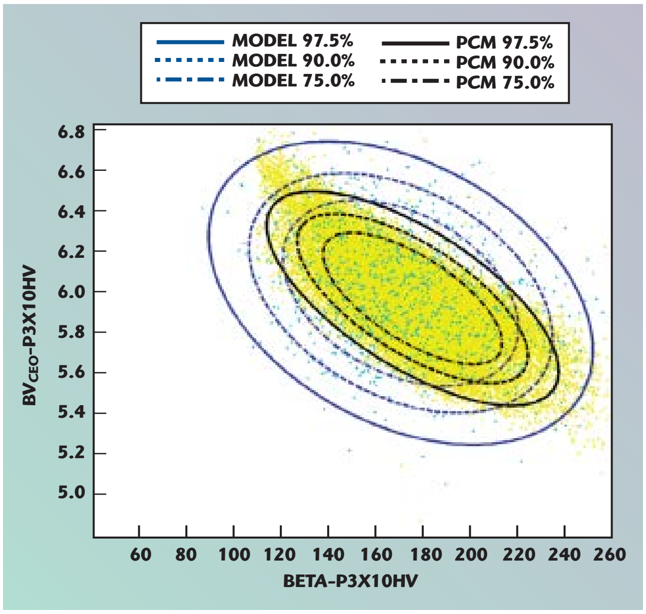
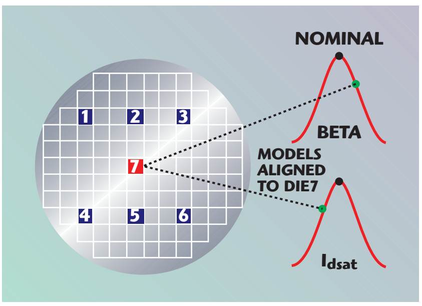


▲ *Fig. 6 Loop closure playback of a SiGe NPN beta vs. breakdown voltage (BV_{ceo}).*

process elements leading to strong statistical PCM correlation. Producing a cohesive and accurate model-to-fab statistical platform is very challenging, and once achieved, needs continual verification. Statistical Loop Closure (SLC) is a DFM-driven methodology that provides a continuous-improvement quality assurance mechanism.

Figure 6 shows a sample output. The scatter plot compares statistical simulation outputs for two PCM parameters vs. the measured PCM equivalents. In this example, a SiGe NPN beta and breakdown voltage are compared. Confidence ellipses are added to illustrate statistical containment probability. The goal of statistical loop closure is to ensure the model and measured parameter correlations and containment ellipses forecast equivalent statistical performance. Beta and breakdown correlate owing to mutual dependence on base and collector doping. The example shows fab measurements running within specification limits and accurately correlated to the statistical model. The Jazz SLC environment is automated to compile monthly reports that include correlation metrics and to send alerts if unexpected drifts are detected.



▲ *Fig. 7 PCMT example.*

PCMT

Closing the gap between simulation results and measured bench data is often the hardest step of a successful design cycle. Designers waste time and resources searching for the root cause of the measured deviations, increasing development costs and time to market. A robust analytical method to evaluate specific semiconductor samples is highly desirable. The Jazz PCMT produces models precisely aligned to the PCM data of a specific silicon sample through a modified statistical BPV engine previously described. PCMT enables insightful correlation of actual silicon IC measurements to circuit simulations, resulting in design optimization and cycle time reduction. PCMT is integrated into the designer wafer in process (WIP) web portal and produces model files easily integrated into the design environment. An example of how PCMT will adapt electrical parameters is shown in ***Figure 7*** for NPN Beta and CMOS I_{dsat}.

CONCLUSION

As the role of microwave circuits as a primary building block of communications systems has expanded into new industries and applications such as AIMS, the lines separating microwave and consumer commodity products have vanished. New breeds of microwave products leverage semiconductor technologies that decisively allow for integration of high-value functionality in a cost-effective manner. As these analog-only circuits evolve into integrated AIMS solutions, a design flow that delivers robust models and

tools intimately tied to the manufacturing process is requisite in the pursuit of performance, manufacturability and optimal time to market. As an example of such a flow, the Jazz RF Analog Design Enablement has been presented as a state-of-the-art methodology that promotes the design of first-time-right optimized microwave modules. Examples of modeling methods, physical design and loop closure tools have been showcased as illustrations of design enablement. In addition to the presented examples, Jazz Semiconductor offers interconnect and substrate parasitic extraction, metal dummy modeling, analog DFM design rules and prefabrication yield estimation. The unique design enablement environment fosters the innovation of highly differentiated microwave technology. ■

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MCA1-12G	7	3800-12000	6.2	38	10.95
MCA1-24LH	10	300-2400	6.5	40	6.45
MCA1-42LH	10	1000-4200	6.0	38	7.45
MCA1-60LH	10	1700-6000	6.3	30	8.45
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MCA1-24MH	13	300-2400	6.1	40	6.95
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GALLIUM NITRIDE MICROWAVE TRANSISTOR TECHNOLOGY FOR RADAR APPLICATIONS

This article reviews the relative merits of silicon (Si), gallium arsenide (GaAs), silicon carbide (SiC) and gallium nitride (GaN) materials and describes how the attributes of each impact the operation of microwave transistors for the generation of high-RF output power, on the order of hundreds to thousands of watts, as necessary for radar systems. It is shown that the superior physical attributes of GaN lead to microwave transistors that are extremely well suited for high power applications. The superior properties of GaN combined with modern high-efficiency biasing techniques make GaN technology a prime candidate for use in transmitters for radar systems.

Many microwave radar transmitters require active devices that can produce RF output power in the order of kilowatts to even megawatts. Routinely, microwave traveling-wave tube devices are utilized for this application. However, the currently used traveling-wave tubes are inefficient, large, expensive and have suspect reliability. While semiconductor-based amplifiers in principle can offer a more effective solution, semiconductor transistors have up until recently been limited in the DC voltage that can be applied to the device by the inherent critical breakdown field that the material can sustain. Since limited DC voltage can be applied, high-RF power operation requires large DC and RF current, which in turn requires large-area devices.[1] High-current operation is inefficient due to series losses and the fact that large-area devices have inherently high capacitance and very low impedance, which limit operating frequency and bandwidth.[1] GaN technology now offers a solution to this dilemma.

Solid-state amplifiers are already replacing traveling-wave-tube amplifiers (TWTA) for a variety of microwave power applications. However, the low operating voltages of Si and GaAs devices lead to a large device periphery, resulting in high device and circuit complexity and reducing production yield and reliability. Wide bandgap technologies like GaN can achieve a power density five times higher than that of conventional GaAs-based metal-semiconductor field effect transistors (MESFET) and heterojunction bipolar transistors (HBT). This will ultimately result in reduced circuit complexity, improved gain and efficiency and higher reliability. In particular, radar systems will benefit from the development of this technology.

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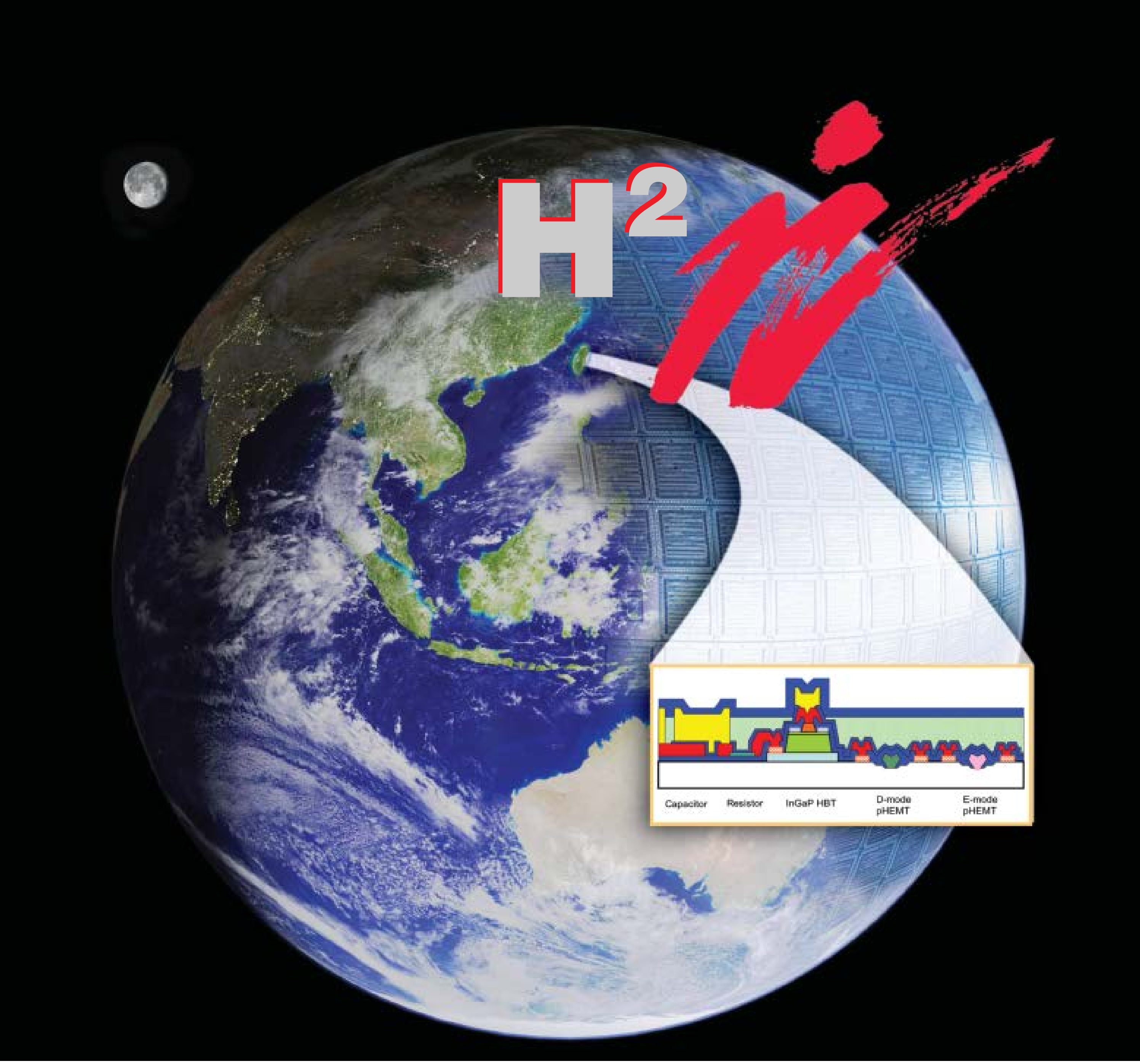

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E-PHEMT	Fmax	90 GHz
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TABLE I

Si, GaAs, SiC AND GaN MATERIAL PROPERTIES

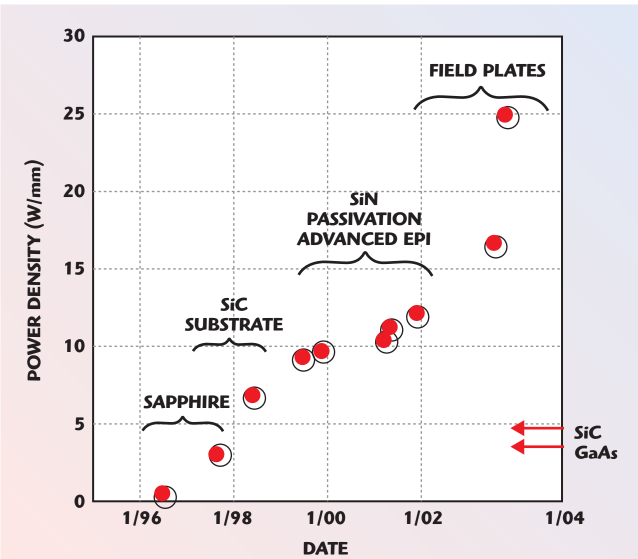
Properties	Si	GaAs	4H-SiC	GaN
Bandgap (eV)	1.11	1.43	3.26	3.42
Relative dielectric constant	11.8	12.8	9.7	9.0
Breakdown field (V/cm)	2.5e5	3.5e5	35e5	35e5
Saturated velocity (cm/sec)	1.0e7	1.0e7	2.0e7	1.5e7
Electron mobility (cm^2/V-sec)	1350	6000	800	1000
Hole mobility (cm^2/V-sec)	450	330	120	300
Thermal conductivity (W/cm-K)	1.5	0.46	4.9	1.7

GaN IS THE FUTURE

The development of wide bandgap semiconductor materials, such as GaN and GaN-based alloys, offers the ability to fabricate RF active devices, specifically AlGaN/GaN power high electron mobility transistors (HEMT), with significantly improved output power performance.[1] The improved RF output power is made possible due to the much improved material properties: high electric breakdown field, high saturated electron drift velocity, and when epitaxially grown on semi-insulating SiC substrates, improved thermal conductivity. The data in ***Table 1***[2] allows a comparison of the most important performance metrics of Si, GaAs, SiC and GaN. The larger thermal conductivity of SiC and GaN enables lower temperature rise due to self-heating. The five to six times higher breakdown field of SiC and GaN is what gives those materials the advantage over Si and GaAs for RF power devices.[2] SiC is a wide bandgap material (3.26eV), but suffers from poor electron transport properties, which hinders its use in very-high-frequency amplifiers. SiC has also been limited by expensive, small and low-quality substrate wafers.

Even though the mobility of the carriers is significantly better for GaAs devices, the higher peak and saturation velocity for GaN HEMTs compensates for its relatively lower mobility, enabling high-frequency performance. These advantages for GaN, with the high linearity and low noise of the HEMT architecture, open the application of these devices for high-power radar amplifiers.

An additional advantage of GaN HEMTs stems from the large conduction band energy offset between the GaN channel and the AlGaN barrier layer. This allows a significant increase in the channel carrier density in GaN-based HEMTs with respect to other materials (up to $10^{13}cm^{-2}$ and above). This, along with higher voltage handling, increases power density. Power density is a very important metric for high-power devices because a higher power density yields a smaller die size and more easily realized input and output matches. The rapid progress in saturated CW RF power densities versus time for GaN FETs at X-band is shown in ***Figure 1***.

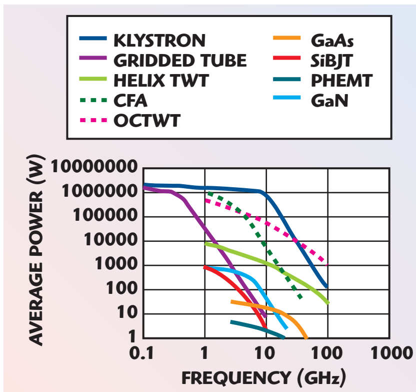


▲ *Fig. 1 Power density for GaN FETs at X-band as a function of year (best values for GaAs and SiC FETs are also shown).*

The high operating voltages and high power densities that are possible with the wide-bandgap RF devices offer a number of advantages for power amplifier design, manufacture and assembly in comparison to Si LDMOS and GaAs MESFET technologies. GaN HEMT technology offers high power per unit channel width that translates into smaller, less expensive devices for the same output power, which are not only easier to fabricate but also increase the impedance of the devices. This enables lower complexity and lower cost impedance matching in amplifiers. The high voltage operation possible with GaN helps in eliminating the need for voltage converters, further reducing system cost.

THE PATH IS CLEAR

The present day state-of-the-art output power vs. frequency for microwave solid-state devices and microwave tubes is shown in ***Figure 2***.[1] Historically, tube amplifiers, such as grid-controlled tubes, magnetrons, klystrons, TWTs and crossed field amplifiers (CFA), have been used as power amplifiers for radar transmitters. These amplifiers generate high power, but usually operate with a low duty cycle. The klystron amplifier offers higher power than the magnetron at microwave frequencies, and also allows the use of more complex waveforms. The TWT is similar to the klystron, but with wider bandwidth. CFAs are characterized by wide bandwidth, modest gain and compactness. Solid-state power amplifiers (SSPA) support long pulses and high-duty-cycle waveforms. Individual SSPA elements can be combined to produce sufficient amplification, despite the fact that individual SSPA elements have low power amplification. Silicon bipolar transistors, gallium arsenide MESFETs and GaAs PHEMTs are some of the solid-state elements used in SSPAs. GaN HEMTs, however, can be combined



▲ *Fig. 2 Present day state-of-the-art microwave tubes and solid-state devices.*

to create a SSPA with a significant improvement in mean output power, resulting in an improvement of the radar detection range.

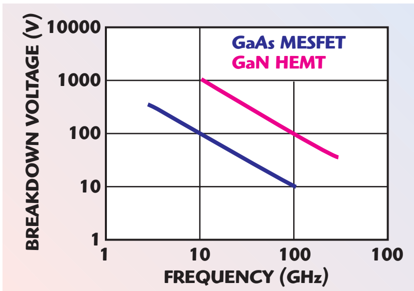
As shown, solid-state transistors produce RF power levels less than about 100 watts at S-band frequencies and below, and their output continuously decreases with increasing frequency.[1] The RF output power capability of GaAs FETs approaches 50 watts at S-band and at Ka-band is limited to approximately one watt.[1] The GaAs FETs are limited in RF output power capability primarily due to the low drain bias breakdown voltage.[1] Semiconductor devices fabricated from wide-bandgap material, such as GaN, offer significantly improved RF performance.

Over time, various figures of merit (FOM) for evaluating semiconductors for high power and high frequency potential have emerged. These FOMs for high performance RF semiconductors attempt to combine the most relevant material properties into a number that provides an estimation of the comparative strengths of the associated materials. The Johnson FOM (JFOM $= E_{CR}\, v_{sat}/\pi$) takes into account the breakdown electric field E_{CR} and the saturated electron velocity v_{sat} and corresponds approximately to the product of device cut-off frequency f_t times the corresponding breakdown voltage. As can be observed from ***Figure 3***,[3] the Johnson FOM for GaN is larger by at least ×15 than that for GaAs.

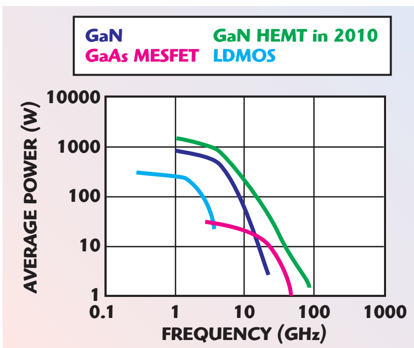
Aethercomm believes that if the trends in GaN advancement are maintained at their current rate, the predicted performance of GaN HEMTs in the year 2010 will be as depicted in ***Figure 4***. As shown, GaN will soon overtake all of its competitors in every category.

EFFICIENCY IS THE KEY

Modern radar systems for military applications place new requirements on RF power amplifiers due to the desire to reduce system size, weight and cost. A major shift in amplifier specifications focuses more on amplifier efficiency to reduce DC power requirements and improve system reliability through lower component power dissipation. Furthermore,



▲ *Fig. 3 Johnson's figure of merit.*



▲ *Fig. 4 Evolution of GaN FET performance.*

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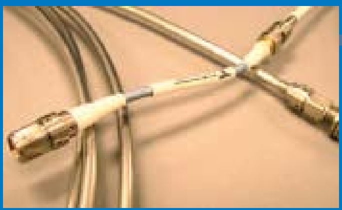

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wide-bandgap, broadband, high-efficiency microwave devices will enable enhanced system capability.

The low parasitic capacitance and high breakdown voltage of GaN HEMTs makes them ideal for realizing the class-E and class-F high efficiency amplifier modes. Both modes have theoretical efficiencies of 100 percent. Recently, several GaN transistor vendors have implemented class-E amplifiers in hybrid form. Typical results are ten watts output power at L-band with efficiencies from 80 to 90 percent.

Aethercomm recently delivered a class-F high efficiency amplifier module operating at L-band to a major defense contractor. The desired output power was to exceed 50 W with an efficiency of 60 percent for the entire amplifier. Due to the tight delivery schedule, it was necessary to use off-the-shelf packaged transistors rather than developing a custom hybrid solution.

The power amplifier final stage was implemented using a balanced pair of packaged GaN HEMTs operating in class-F. Matching networks supplying the harmonic terminations necessary for class-F operation were designed by starting with an idealized model of the transistor. The parasitic capacitance and inductance of the transistor package was then added and the matching networks were modified appropriately to maintain the required harmonic terminations at the transistor die. The amplifier was then simulated using a nonlinear model of the transistor and the matching networks were modified to optimize efficiency and power.

A single-ended prototype of the class-F output stage was constructed. Drain efficiency of 75 percent, output power of 40 W and gain of 16 dB were obtained with only minor bench tuning. The results tracked the simulation closely. Low power GaN devices suitable for the driver stage were not available. The three-stage driver was designed using GaAs MESFETs, which were operated in class-A. Initially, it was believed that the driver stages would have to be operated in a high efficiency mode in order to achieve the required PAE; however, analysis indicated that with proper sizing of the transistors, class-A operation was permissible. The driver had 40 dB gain and 10 W power consumption.

The final configuration of the power amplifier exhibited a peak PAE of 63 percent at an output power of 75 W. At P2dB, the amplifier had an output power of 65 W and 61 percent PAE. ***Table 2*** gives the characteristics of the power amplifier under different drive levels. Since the class-F final stage is biased at threshold, with no quiescent current, the amplifier has gain expansion at low drive levels. The amplifier gain peaks then compresses as the maximum output power is approached. Table 2 demonstrates the efficiency of this design.

Aethercomm has also tested a 200 W GaN HEMT device on SiC substrate designed to maximize power-added efficiency while maintaining a high output power for an operating frequency of 1215 to 1390 MHz and has observed efficiencies greater than 56 percent while maintaining output power levels in excess of 205 W at P3dB.

TABLE II

L-BAND CLASS-F HIGH-EFFICIENCY AMPLIFIER

RF Output Power (dBm)	Gain (dB)	DC Power (W)	PAE (%)	RF Output Power (dBm)	Gain (dB)	DC Power (W)	PAE (%)
38.3	53.3	34.7	19.5	47.8	52.8	103.9	58.0
40.7	53.7	44.3	26.5	48.2	52.2	110.1	60.0
42.9	53.9	56.6	34.5	48.5	51.5	114.6	61.8
44.9	53.9	71.6	43.2	48.7	50.7	117.8	62.9
46.6	53.6	88.5	51.7	48.8	49.8	120.0	63.2

Many SSPAs intended for radar applications are designed with semiconductor RF devices configured for class-C operation. This form of bias yields very efficient operation for a single transistor stage; however, the class-C transistor has such low gain, typically 6 dB, that the efficiency advantage is lost due to the fact that many additional stages of gain are required to achieve the desired output power.

CONCLUSION

Future radar systems such as the active phased-array radar (APAR) will require increasingly smaller, more highly efficient SSPAs. The desire for extremely fast scanning rates, much higher range, the ability to track and engage a tremendous number of targets, low probability of intercept, and the ability to function as a radio/jammer will require an innovative and cost-effective transistor technology. Recent developments in the GaN HEMT have made it possible to realize highly efficient amplifiers at microwave frequencies. GaN HEMT devices provide a very high ratio of peak current to output capacitance, as well as an extremely high breakdown voltage and power density capability. This unique combination of characteristics allows designers freedom to achieve higher overall amplifier performance compared to competing devices. ■

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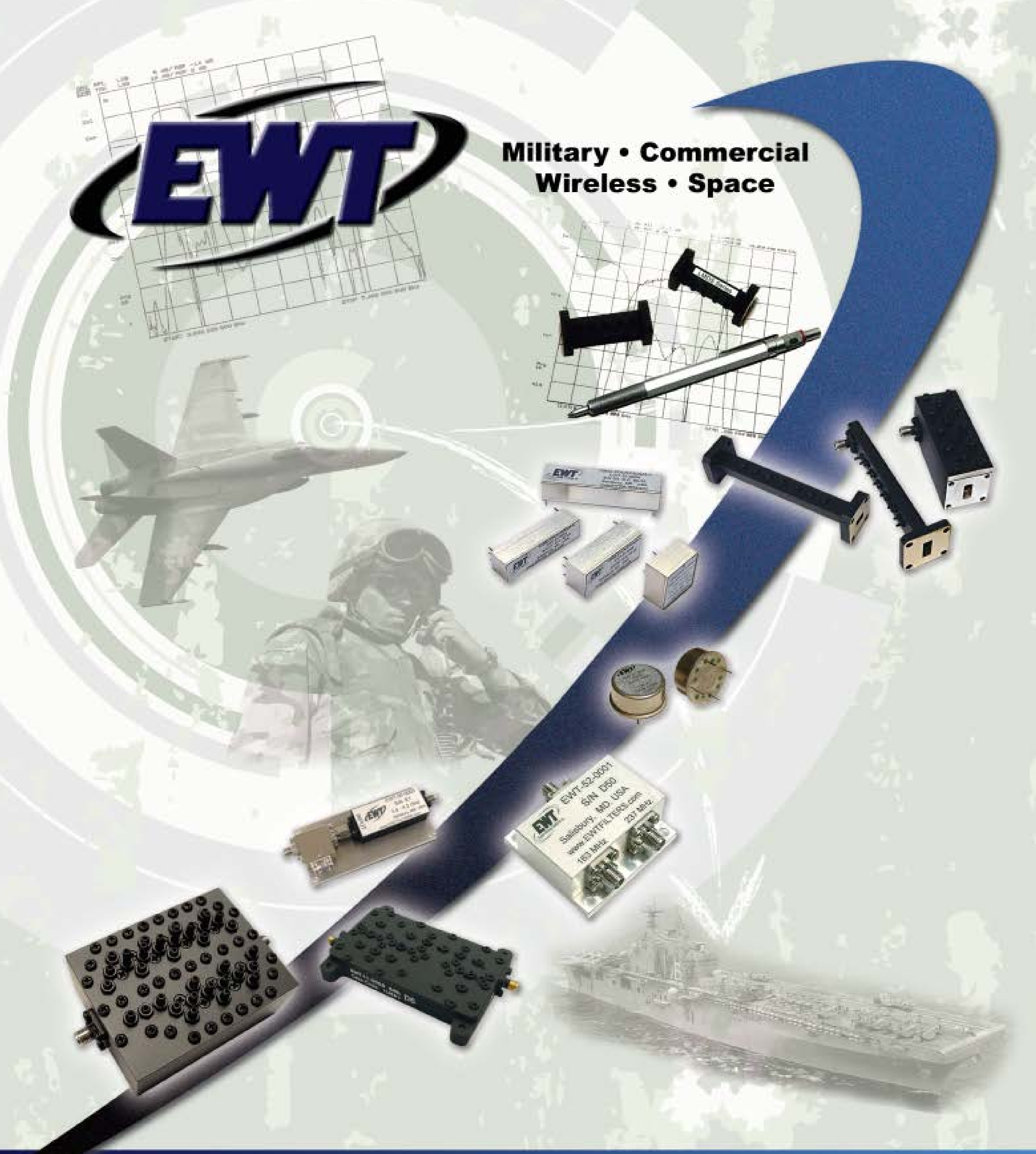

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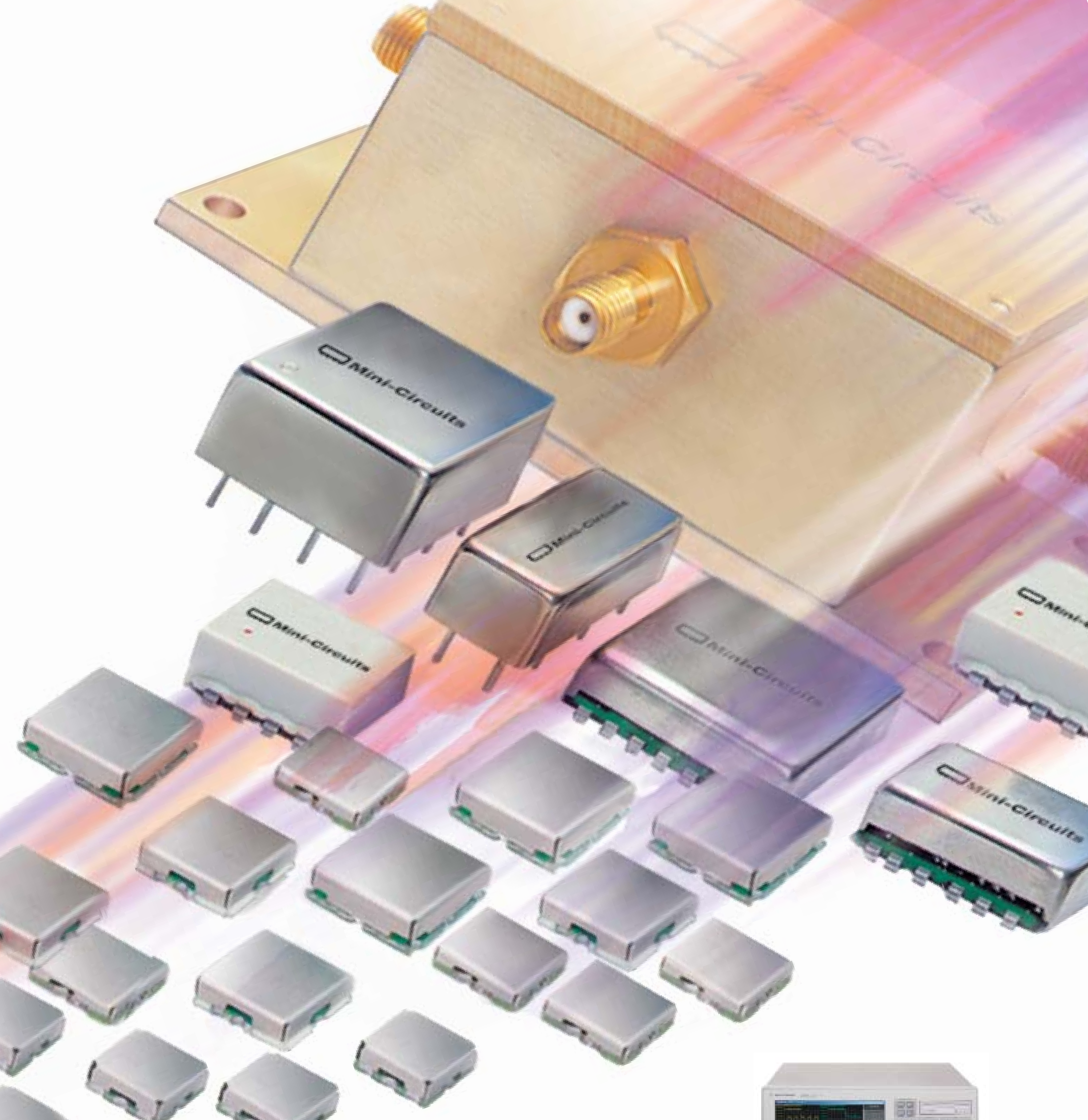

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A DUAL-MODE SENSOR SOLUTION FOR SAFE HELICOPTER LANDING AND FLIGHT ASSISTANCE

Helicopters are in danger of suffering damage, collision or crashes when taking off and landing in brown-out/white-out conditions. This article provides an overview of how new developments in radar and laser technology and particularly sensor fusion can enhance the safety of helicopter missions

During take off and landing flight phases, helicopters can encounter serious brown-out or white-out problems in dusty, sandy or snowy areas as the downwash of the rotor blades creates dust clouds that can completely engulf the helicopter. This is graphically illustrated in ***Figure 1***. During landing in particular, the loss of visual references means that wires, poles and other obstacles represent a potential hazard for helicopters.

The substantial risk of flying in such brown-out/white-out conditions can result in the loss of orientation and positional awareness, which can lead to the following consequences:

- A hard landing, possibly exceeding the limits of the landing gear
- A collision with obstacles during in-cloud drifting or go-around
- A so-called vertigo situation (spatial disorientation)
- Accidental rolling of the helicopter in the air or on the ground due to the unevenness of the landing surface
- Non-identification of approaching/moving objects

CURRENT MEASURES

No optimal technical solution for brown-out/white-out conditions is available today, but those involved in the avionics industries worldwide are working to develop an aid to overcome this problem. With no technological solution currently available, however, the only current measure to reduce the risk is pilot training, which is limited in its effectiveness.

YAN CHRISTIAN VENOT AND
PETER KIELHORN
EADS Defence & Security
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▲ *Fig. 1 Dust clouds completely engulfing a landing helicopter.*

POSSIBLE TECHNOLOGIES

Work is currently being carried out to develop technology that can solve the problem. The optimal solution will be sensor technology that can provide a "see-through" visibility that has the capability to detect all kinds of obstacles, from large objects down to dangerous thin wires. As it is mostly military helicopters that are affected by brown-out/white-out conditions, however, it is essential that any solution does not increase the helicopter's probability of detection/identification.

Recent technology evaluations have led to the perception that the optimum solution requires the combination of several (at least two) sensor technologies. This article will outline the use of several sensor technologies—radar and laser radar (ladar)—as well as database-driven capabilities, namely 2.5D/3D map and ground collision avoidance systems, whose complementary combination will provide the necessary solution.

THE SENSORS

Starting with radar, the maximum performance of a radar sensor system is achieved by combining the hard-

ware modules with powerful radar algorithms, and resolution in azimuth is enhanced by applying synthetic-aperture radar (SAR) and inverse-SAR (ISAR) techniques. Also, range-Doppler processing facilitates the discrimination between moving and stationary targets, which is a basic feature needed in safety applications.

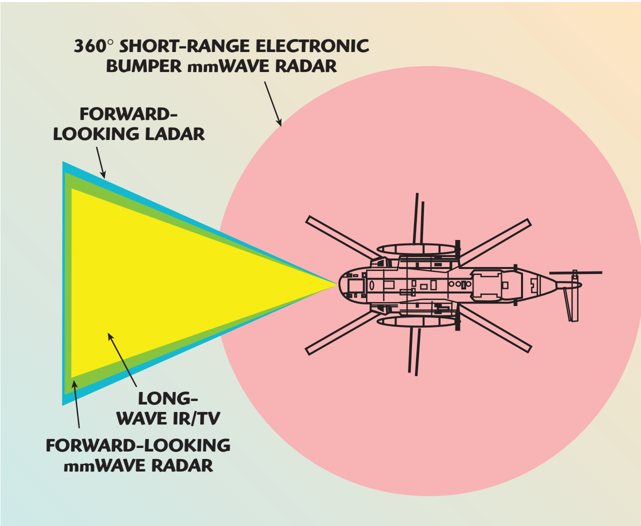

Fig. 2 The sensor coverage around a helicopter.

Secondly, ladar is analogous to millimeter-wave radar in its imaging capabilities, but uses laser beams to scan an area. Reflected laser light is processed to create a virtual picture of the area. Using pulsed-laser technology, ladars perform 3D scanning of the environment in front of the helicopter. The resultant geo-referenced 3D data is analyzed by sophisticated algorithms to identify helicopter endangering obstacles and terrain and provide reliable warnings.

THE SOLUTION

By fusing the sensors described, the ultimate aim is to extend the helicopter's operational envelope to 24 hours a day, seven days a week, in whatever the weather can throw at it. This basically means flying in zero visibility to the naked eye, close to zero light conditions and in all weather conditions.

To achieve such a 24/7, all-weather situational awareness suite requires three integral steps. In Step 1, the landing aid combines a ladar 3D see and remember capability, which provides a high-resolution visualization of the landing zone, with a millimeter-wave radar system that detects approaching/moving objects in a 360° area around the helicopter (also known as the electronic bumper capability).

This solution provides obstacle collision/terrain approximation warning during helicopter flight and a visual landing aid/symbology with moving/approaching object indication for landing in a degraded visual environment.

The ladar's 3D see and remember visualization is based on the raw data gathered during the landing approach. As long as the landing area is unobscured on approach, the raw ladar data will be used for area visualization with active obstacle/terrain collision warning, which is also stored in the unit's memory. When the pilot's view of the landing area starts to become obscured due to brown-out or white-out conditions, the pilot can command the memory freeze and remember function of the ladar with the electronic bumper function of the millimeter-wave radar.

The resulting degraded visualization is composed of the 3D landing area display correlated to the position and movement of the helicopter, the hover symbology in a so-called "followers view," representing current height, drift, drift speed and the artificial horizon, as well as the warning display of the 360° electronic bumper.

The main features of this method are detection, localization and collision avoidance of stationary objects in the dedicated landing area, moving object identification (MOI) to ensure that no additional objects enter the landing area and analysis of the landing spot (for example, inclination and vegetation). By correlating radar data from various channels, a very precise drift measurement is available for dedicated operations and the electronic bumper avoids collisions with

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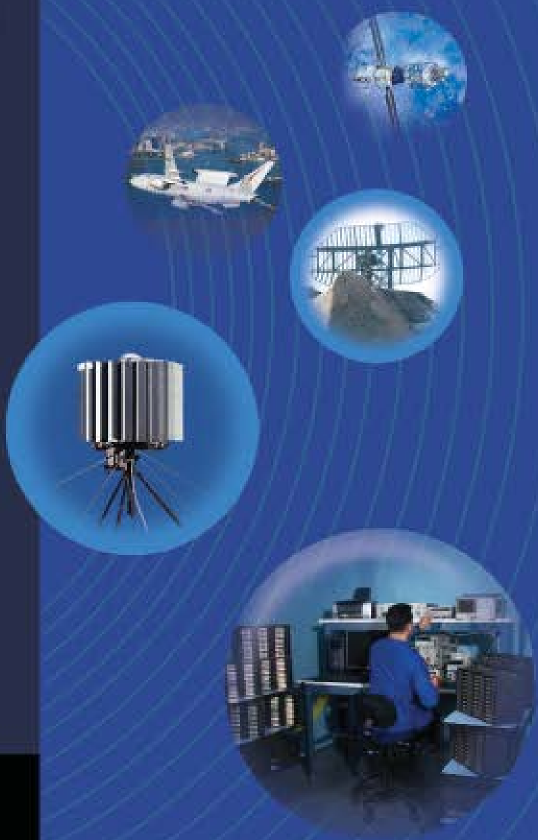
** Note: Bandwidth dependent.*



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other helicopters during the landing operation.

Step 1 provides a solution for obstacle collision and approximating terrain protected flight in expected weather conditions together with an aid for safe landing in a degraded visual environment.

Step 2 extends the flight protection capability to a degraded visual environment. This can be realized by adding forward-looking millimeter-wave-based vision radar to the system and by improving the ladar with regards to multi-pulse processing and timing control. The resulting sensor data is combined in such a way that both data sets are digitally combined/fused and the resulting information is used to provide improved visualization as well as optimized obstacle collision and terrain approximation warning.

Figure 2 identifies the sensor coverage around the helicopter. Note that the scale of the forward-looking sensor range is not identical to the 360° electronic bumper range.

Finally, Step 3 brings to fruition a comprehensive 24/7 situation awareness suite for helicopters. This step adds a digital map system with flight/situation planning and Jeppesen support. The digital terrain elevation data (DTED) database for the map system is enhanced dynamically in-flight and/or during flight planning with current or recorded ladar 3D digital world data. The ladar system can generate and deliver, in real-time, high-resolution 3D digital world data in the standard DTED format with a resolution of level four or better. This data can be used on-board for the improvement of the map system or can be recorded for future flight/mission planning.

FURTHER DEVELOPMENTS

Studies are currently being conducted to characterize radar RF parameters of dust clouds in landing areas. The results will strongly influence the design of the optimum sensor system (for example, choice of frequency). Also under consideration are evaluations of ladar behavior in dust clouds with a view to improved capabilities in terms of receiver management, multi-pulse application and laser pulse timing. ■

Yan Christian Venot *has his PhD degree in radar engineering and hyper frequencies, and is currently product manager for radar seekers and mm-wave sensor applications at EADS Defence & Security. He has experience in the managing of projects in the civil and military fields. His technical background is hardware design and realization, high frequency field simulation as well as system engineering in radar sensors and radar seeker applications.*

Peter Kielhorn *has his engineering diploma in information technology. He is currently project and product manager for military obstacle/terrain avoidance system (HELLAS-Awareness) and is responsible for future ladar applications at EADS Defence & Security. He joined the company in 1984 (at that time it was Dornier GmbH) and has experience in managing projects in military reconnaissance applications and the ladar equipment field. His technical background is systems/embedded software design and realization as well as system engineering for airborne reconnaissance applications.*

A MULTI-BAND INSERTED YAGI-TYPE ARRAYED-SLOTS PIFA ANTENNA USING A LARGE OFFSET RECTANGULAR L-SHAPED FEED

By inserting Yagi-type arrayed-slots on a metallic plate placed on a foam base with a large offset U-L-shaped feed, a low-cost, surface-mount, planar inverted-F antenna (PIFA), suitable for cellular, PCS, IMT-2000 multi-band operations, is realized. The antenna has a 37 × 25 × 7.5 mm compact size. The proposed antenna can easily be constructed at low cost, and has a low antenna height above the ground plane of the system circuit board. In this case, a large offset U-L-shaped feed line leads to good impedance matching over a wide frequency band. Inserted Yagi-type arrayed-slots on the patch element act as multi-band resonant elements of the antenna. This article presents experimental results of a constructed prototype, covering the usable bandwidths of the cellular (0.824 to 0.96 GHz), GSM (0.86 to 0.88 GHz), DCS (1.71 to 1.88 GHz), PCS (1.85 to 1.99 GHz) and IMT-2000 (1.90 to 2.20 GHz) operations.

Along with monopole, patch and slot antennas, the inverted-F antenna (IFA) has become of primary importance for portable and handheld wireless communication units. It is known as a high-efficiency, quasi-omni-directional antenna, with a height of approximately 0.05 to 0.1λ, which is 2.5 to 5 times shorter than a quarter-wave monopole.[1–4] The wire or planar inverted-F antenna (PIFA) is a low-profile modification of the quarter-wave monopole, and thus belongs to the group of unbalanced antennas. The demand for smaller communication devices for personal communication systems has led to a constant search for methods to reduce cellular phone dimensions. However, the wavelength does not decrease at the same rate as the size of the mobile phone, due to the higher frequency band used. Even a quarter-wavelength

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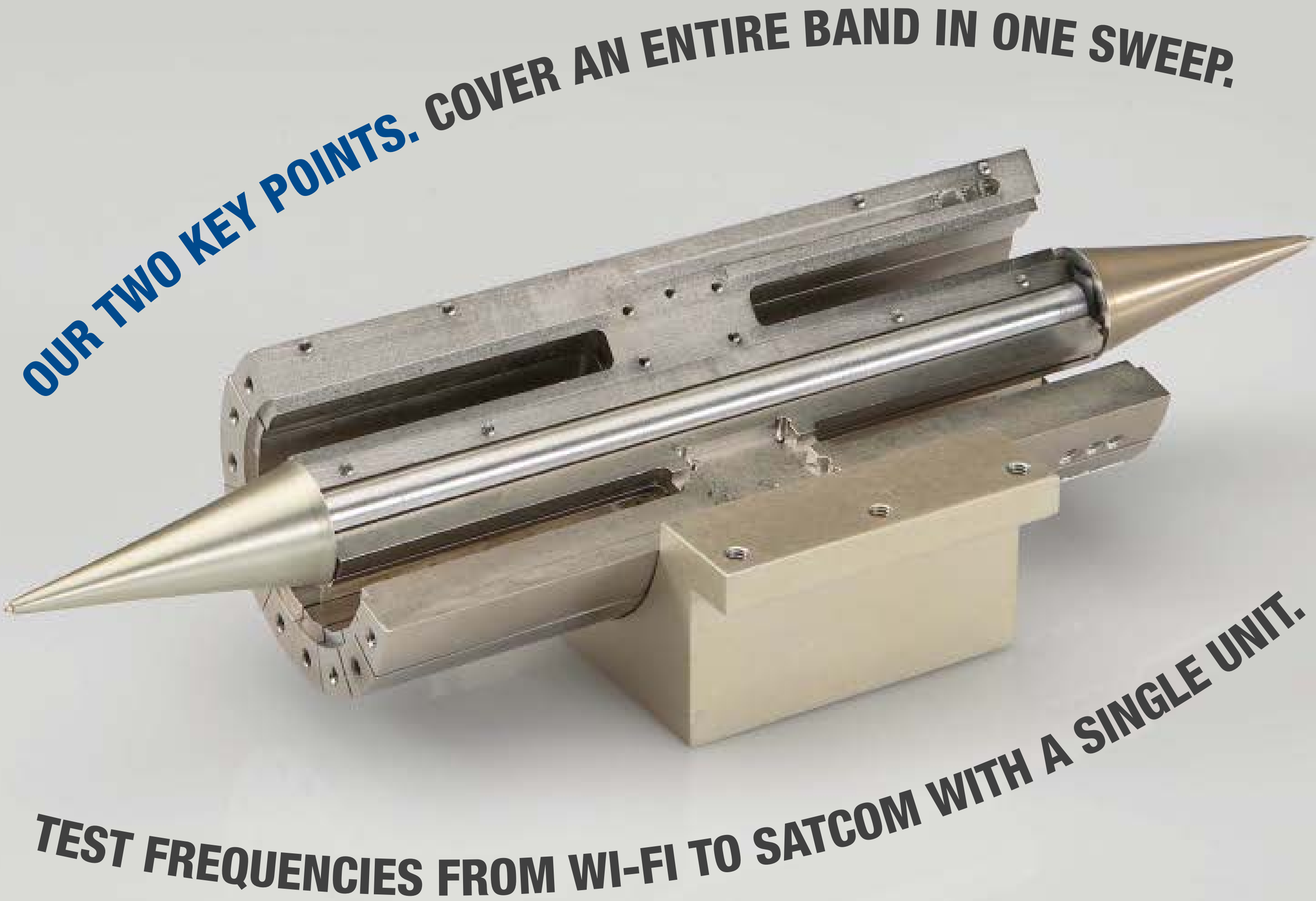
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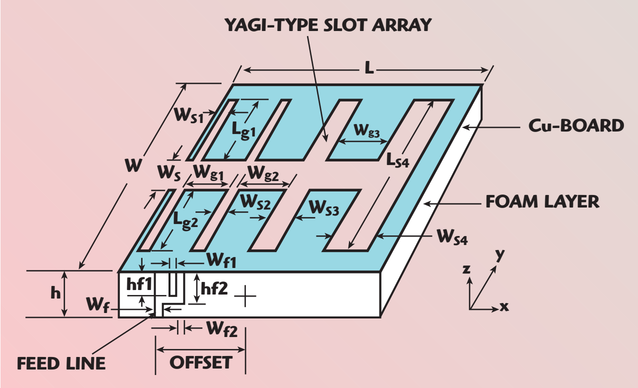
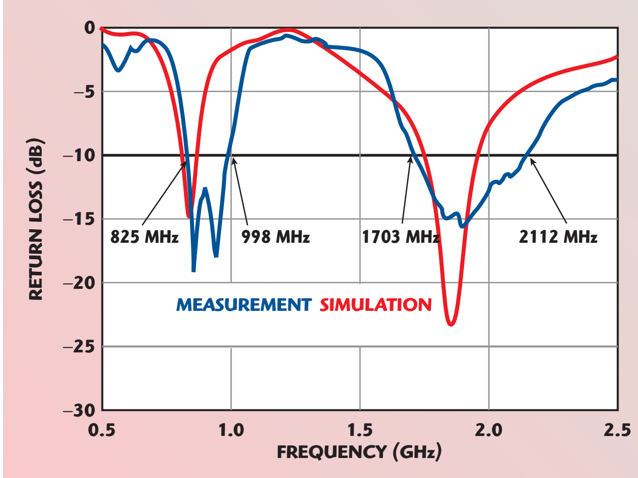


▲ *Fig. 1 Structure and dimensions of the proposed antenna.*

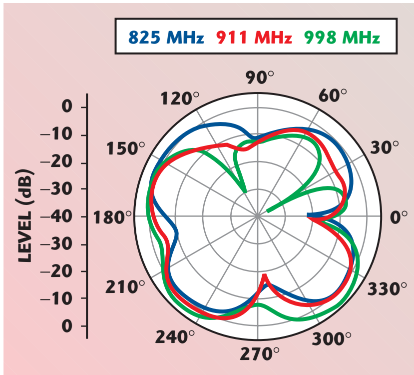


▲ *Fig. 2 Comparison between simulated and measured return loss of the proposed antenna.*

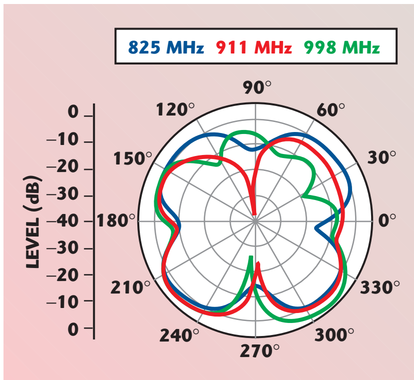
antenna, such as the PIFA, tends to become large for a cellular phone. In this article, a novel PIFA structure, with inserted Yagi-type arrayed-slots and using a large offset rectangular L-shaped feed line is described, which has similar radiation pattern properties, but with the advantage of being multi-band compared to a conventional PIFA.[2,4–6] The proposed antenna has a lower profile and a smaller size than a conventional PIFA.[1–6] This article also describes the simulated and measured results for multi-band performance and experimental gain and the radiation patterns.

ANTENNA STRUCTURE AND DESIGN PARAMETERS

The structure of the proposed antenna is shown in ***Figure 1***. It consists of a metallic plate on a foam substrate, with a Yagi-type array of etched slots and a large offset U-L-shaped feed line. A rectangular L-shaped microstrip feed line is proposed to match the input impedance of the antenna. A large offset U-L-shaped feed line is used to extend the bandwidth proportionally to the slot width. The feeding structure of the proposed antenna leads to an impedance matching over a wide frequency band and is better than the conventional feed line



▲ *Fig. 3 Measured radiation patterns in the x-y plane at the lower band.*

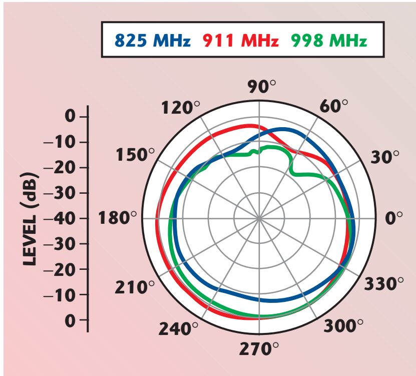


▲ *Fig. 4 Measured radiation patterns in the y-z plane at the lower band.*

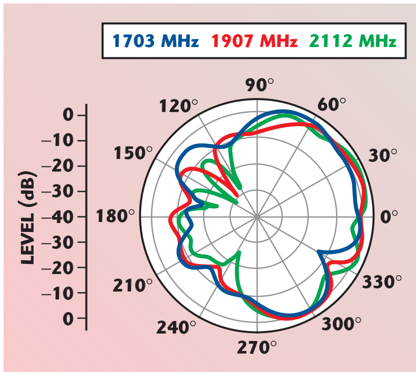
structures. The proposed antenna can easily be constructed at low cost and has a low antenna height above the ground plane of the system circuit board. The inserted Yagi-type etched-slot array on the patch element acts as multi-band resonant elements of the antenna. The width of each slot was etched to a different size, but the length of the slots was kept the same. L_{s1} is the length of the slots, W_{s1} is the width of the first slot, W_{s2} is the width of the second slot, W_{s3} is the width of the third slot, W_{s4} is the width of the fourth slot, W_{g1} is the gap between the first and second slots, W_{g2} is the gap between the second and third slots, W_{g3} is the gap between the third and fourth slots, W_f is the width of the feed line, W_{f1} and h_{f1} are the width and height of the etched internal part of the U-shaped feed line, and W_{f2} and h_{f2} are the width and height of the right part of the U-shaped feed line. The optimized antenna dimensions are: $W_{s1} = W_{s2} = 1$ mm, $W_{s3} = 3$ mm, $W_{s4} = 5$ mm, $L_{g1} = 8$ mm, $L_{s4} = 20$ mm, $W_{s4} = 5$ mm, $W_{g1} = 8$ mm, $W_{g2} = 9$ mm, $W_{g3} = 8$ mm, $W_f = 3.0$ mm, $W_{f1} = 1.1$ mm, $W_{f2} = 2$ mm, $h_{f1} = 4.5$ mm, $h_{f2} = 6$ mm, offset = 13 mm. The antenna characteristics are sensitive to the design parameters (L_{s1}, W_{s3}, W_{s4}, L_{s4}, W_f, W_{f1}, W_{f2}, h_{f1}, h_{f2}) and depend highly on the offset.

SIMULATION AND EXPERIMENTAL RESULTS

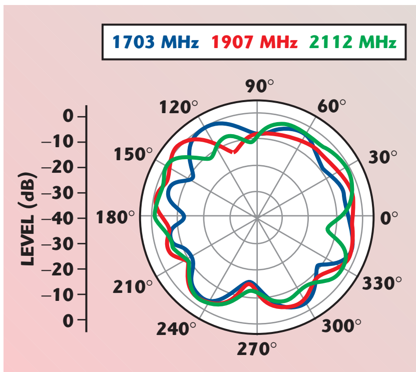
The proposed antenna was designed using the commercial program CST Microwave Studio.[7] The antenna was fabricated using a Cu-board and foam layer (h = 1.0 mm) with overall dimensions of 37 × 25 × 7.5 mm. The antenna measurements were made with an HP8510B network analyzer. ***Figure 2*** shows a comparison of the simulated and measured return loss of the proposed antenna. The experimental impedance bandwidth is approximately 825 to 998 MHz (20 percent at the 865 MHz center frequency) and 1703 to 2112 MHz (21.5 percent at the 1900 MHz center frequency) for an S_{11} less than –10 dB, and covers the cellular, PCS, IMT-2000 and WLL bands. After calibration using a horn antenna, the radiation patterns in the far field were measured. The measured radiation patterns in the x-y plane for the proposed antenna at 825, 911 and 998 MHz are shown in ***Figure 3***. The measured radiation patterns in the y-z plane for the proposed antenna at the lower band are shown in ***Figure 4***. The measured radiation patterns in the x-z plane for the proposed antenna at the lower band are shown in ***Figure 5***. In the higher band, the measured radiation patterns in the x-y, y-z and x-z planes for the proposed antenna are



▲ *Fig. 5 Measured radiation patterns in the x-z plane at the lower band.*



▲ *Fig. 6 Measured radiation patterns in the x-y plane at the higher band.*



▲ *Fig. 7 Measured radiation patterns in the y-z plane at the higher band.*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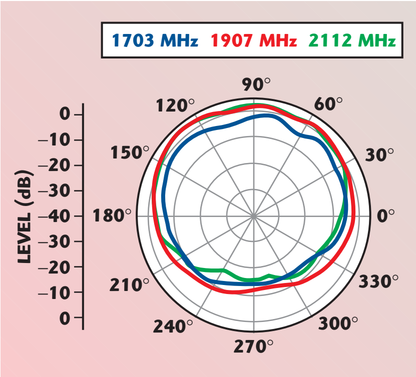
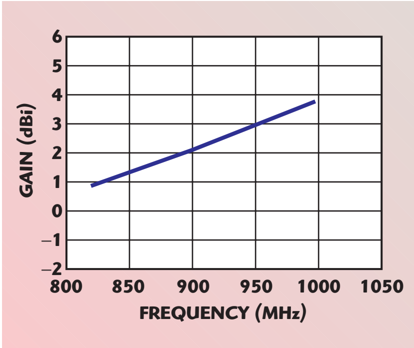
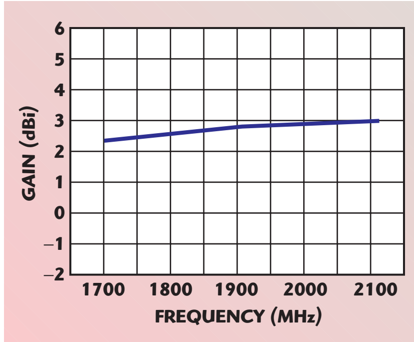


▲ *Fig. 8 Measured radiation patterns in the x-z plane at the higher band.*



▲ *Fig. 9 Measured antenna gain in the lower band.*



▲ *Fig. 10 Measured antenna gain in the higher band.*

also shown in ***Figures 6***, ***7*** and ***8***, respectively. The radiation patterns at these operating bands are similar to those of a simple microstrip patch antenna. The radiation characteristics of the proposed antenna are seen to have asymmetric characteristics. This is due to the basic characteristics of a planar structure. However, no prominent difference between the radiation patterns at these operating bands are seen. This suggests that the radiations are stable in the operating band for PCS, IMT-2000 and WLL operations. ***Figure 9*** shows the measured antenna gain for operating frequencies across the lower band (cellular and GSM). ***Figure 10*** shows the measured antenna gain for operating frequencies across the higher band (PCS, IMT-2000 and WLL). The peak antenna gain is approximately 3.6 and 2.6 dBi for the lower (cellular, GSM) and the higher (DCS, PCS, IMT-2000, WLL) operations, respectively.

CONCLUSION

In this article, a novel PIFA antenna structure is described, consisting of an inserted Yagi-type array of slots and using a large offset U-shaped feed for cellular, PCS and IMT-2000 operations. The proposed antenna can easily be constructed at low cost, and has a low antenna height above the ground plane of the system circuit board. In this case, a large offset U-shaped feed leads to good impedance matching over a wide frequency band. The inserted Yagi-type slot-array on the patch element acts as a multi-band resonant element at the usable frequencies. The experimental impedance bandwidths are approximately 825 to 998 MHz (20 percent bandwidth) and 1703 to 2112 MHz (21.5 percent bandwidth) for an S_{11} less than –10 dB, covering the cellular, PCS and IMT-2000 operations for mobile communications. Good radiation characteristics have also been observed. ■

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IRM0812(*)C2(**)	8 – 12	8	18	20
IRM1218(*)C2(**)	12 – 18	10	18	20
IRM0208(*)C2(**)	2 – 8	9	18	18
IRM0618(*)C2(**)	6 – 18	10	18	18
IR1826NI7(**)	18 – 26	10.5	18	20
IR2640NI7(**)	26 – 40	12	18	20

Model Number	RF/LO Frequency (GHz)	Conversion Loss (dB) Max.	Balance Phase (±Deg.) Typ./Max.	Balance Amplitude (±dB) Typ./Max.	LO-to-RF Isolation (dB) Min.
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IRM0408(*)C2Q	4 – 8	11	7.5/10	1.0/1.5	20
IRM0812(*)C2Q	8 – 12	11	5/7.5	.75/1.0	20
IRM1218(*)C2Q	12 – 18	13	10/15	1.0/1.5	20
IRM0208(*)C2Q	2 – 8	12	7.5/10	1.0/1.5	18
IRM0618(*)C2Q	6 – 18	13	10/15	1.0/1.5	18
IR1826NI7Q	18 – 26	13.5	10/15	1.0/1.5	20
IR2640NI7Q	26 – 40	15	10/15	1.0/1.5	20

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SSM0408(*)C2MD(**)	4 – 8	9	20	18
SSM0812(*)C2MD(**)	8 – 12	9	20	20
SSM1218(*)C2MD(**)	12 – 18	10	20	18
SSM0208(*)C2MD(**)	2 – 8	9	20	18
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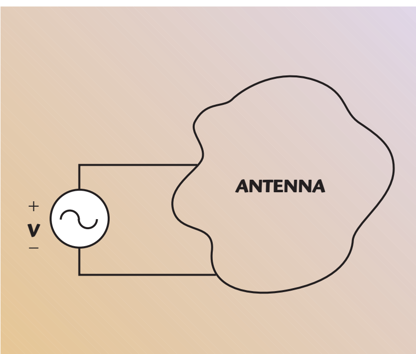
POWERFUL NEW FORMULAS FOR INPUT IMPEDANCE OF ANTENNAS AND ARRAYS

Some methods of antenna modeling and measurement lead directly to radiation patterns and total radiated power without the intermediate, and often tedious or impractical, step of calculating self and mutual impedances.[1] Still, it is often desirable and necessary to know the input impedance for each element in the array. This article describes novel formulas for determining the input conductance or resistance without knowing a priori any self and mutual impedances. By determining the conductance, the susceptance is also determined because they are Hilbert transform pairs. Similarly, resistance and reactance are also Hilbert transform pairs.

Fig. 1 A single antenna.



FORMULA FOR SINGLE ANTENNA

To begin with the simplest case, a single antenna as shown in ***Figure 1***, for which the input voltage V and the total radiated power P is considered.

The radiated power and input voltage are related by the input conductance G, according to the formula

$$P = G|V|^2 \qquad (1)$$

The voltage, in general, is a complex quantity with nonzero amplitude and phase

$$V = Ae^{j\alpha} \qquad (2)$$

Using Equation 2, Equation 1 becomes

$$P = GA^2 \qquad (3)$$

The first derivative of P is

$$\frac{\partial P}{\partial A} = 2AG \qquad (4)$$

The second derivative is

$$\frac{\partial^2 P}{\partial A^2} = 2G \qquad (5)$$

JEREMY K. RAINES
Consultant

Solving Equation 5 for the input conductance yields

$$G = \frac{1}{2}\frac{\partial^2 P}{\partial A^2} \quad (6)$$

Next, Equation 6 is generalized for an antenna array with any number of elements.

FORMULA FOR ANTENNA ARRAY

Figure 2 shows an antenna array with N elements. The total radiated power P and the input voltages V_n are related to the input conductances G_n according to the formula

$$P = \sum_{n=1}^{N} G_n |V_n|^2 \quad (7)$$

The voltages are complex, with nonzero amplitude and phase

$$V_n = A_n e^{j\alpha_n} \quad (8)$$

Using Equation 8, Equation 7 becomes

$$P = \sum_{n=1}^{N} G_n A_n^2 \quad (9)$$

According to Equation 9, the first derivative of P with respect to the voltage amplitude at the input of the mth element is

$$\frac{\partial P}{\partial A_m} = \sum_{n=1}^{N}\left(\frac{\partial G_n}{\partial A_m}A_n^2 + 2A_n\frac{\partial A_n}{\partial A_m}G_n\right) \quad (10)$$

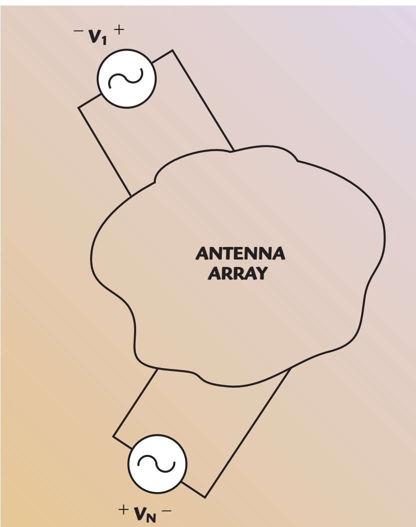


Fig. 2 *A antenna array with N elements.*

On the right side of Equation 10, the first term is simply the mutual conductance between the mth and nth elements

$$\frac{\partial G_n}{\partial A_m} = G_{nm} = G_{mn} \quad (11)$$

The voltage amplitudes are determined independently by the sources, so that

$$\frac{\partial A_n}{\partial A_m} = \begin{cases} 0 & n \neq m \\ 1 & n = m \end{cases} \quad (12)$$

Using Equations 11 and 12, Equation 10 becomes

$$\frac{\partial P}{\partial A_m} = \sum_{\substack{n=1 \\ n\neq m}}^{N} G_{nm}A_n^2 + 2A_mG_m \quad (13)$$

Using Equation 13, the second derivative of P with respect to A_m is

$$\frac{\partial^2 P}{\partial A_m^2} = \sum_{\substack{n=1 \\ n\neq m}}^{N}\left(\frac{\partial G_{nm}}{\partial A_m}A_n^2 + 2A_n\frac{\partial A_n}{\partial A_m}G_{nm}\right) + 2G_m \quad (14)$$

The mutual conductance G_{nm} depends only on the geometry of the array and the wavelength. It is independent of voltage, that is

$$\frac{\partial G_{nm}}{\partial A_m} = 0 \quad (15)$$

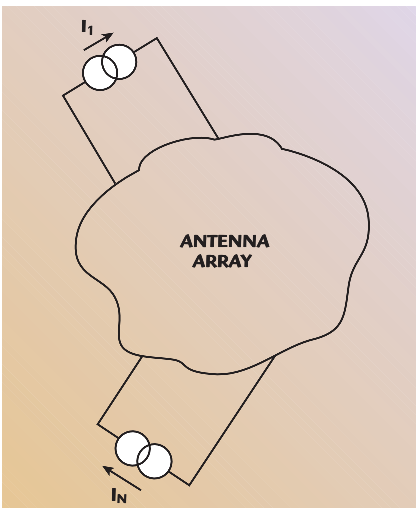


Fig. 3 *A antenna array with current sources.*

Using Equations 12 and 15, Equation 14 simplifies to

$$\frac{\partial^2 P}{\partial A_m^2} = 2G_m \quad (16)$$

Solving Equation 16 for the input conductance of the mth antenna element yields

$$G_m = \frac{1}{2}\frac{\partial^2 P}{\partial A_m^2} \quad (17)$$

Equation 17 is not only rigorous, it is also intuitively appealing. It proposes that if the amplitude A_m of the mth voltage source is perturbed, then the more the total radiated power P is affected, the greater the input conductance G_m must be.

In numerical modeling or experimental work, the second derivative on the right side of Equation 17 may be approximated by finite differences so that

$$G_m = \frac{1}{2}\frac{\frac{P_1 - P_0}{\Delta A_m} - \frac{P_0 - P_2}{A_m}}{\Delta A_m} \quad (18)$$

On the right side of Equation 18, P_0, P_1 and P_2 are distinct and separate total radiated powers corresponding to different values of A_m. With a little algebra, Equation 18 simplifies to

$$G_m = \frac{P_1 + P_2 - 2P_0}{2(\Delta A_m)} \quad (19)$$

FORMULA FOR ANTENNA ARRAY WITH CURRENT SOURCES

Similar formulas for the input resistance may be derived if the excitations are current sources instead of voltage sources, as shown in ***Figure 3***.

The total radiated power P is related to the current sources I_n by the input resistance R_n

$$P = \sum_{n=1}^{N} |I_n|^2 R_n \quad (20)$$

The currents are complex, with nonzero amplitude and phase

$$I_n = B_n e^{j\beta_n} \quad (21)$$

Following steps analogous to those in the previous section, the input resistance to the mth antenna in the array is

$$R_m = \frac{1}{2}\frac{\partial^2 P}{\partial B_m^2} \qquad (22)$$

Equation 22 is intuitively appealing in the same way as Equation 17. It tells us that if we perturb the amplitude B_m of the mth current source, then the more the total radiated power P is affected, the greater is the input resistance R_m.

ANTENNA SUSCEPTANCE AND REACTANCE

So far, the formulas have explicitly described only the real part of antenna input impedance or admittance, that is, the resistance or conductance. Rigorously, however, the imaginary parts have also been determined. This is because the real and imaginary parts of impedance, admittance and of all realizable physical phenomena are not independent. One uniquely determines the other.[2] For example, susceptance and conductance determine each other, according to the formulas

$$B(\omega) = \frac{1}{\pi}\int_{-\infty}^{\infty}\frac{G(\xi)}{\omega-\xi}d\xi \qquad (23)$$

$$G(\omega) = -\frac{1}{\pi}\int_{-\infty}^{\infty}\frac{B(\xi)}{\omega-\xi}d\xi \qquad (24)$$

Equations 23 and 24 are called Hilbert transform pairs. To make practical use of those equations, B or G must be known over a wide spectrum of frequency

$$\omega = 2\pi f \qquad (25)$$

Reactance and resistance are similarly related by Hilbert transforms

$$X(\omega) = \frac{1}{\pi}\int_{-\infty}^{\infty}\frac{R(\xi)}{\omega-\xi}d\xi \qquad (26)$$

$$R(\omega) = -\frac{1}{\pi}\int_{-\infty}^{\infty}\frac{X(\xi)}{\omega-\xi}d\xi \qquad (27)$$

In principle, Equations 17 and 23 could be used to determine the antenna input susceptance B. Similarly, Equations 22 and 26 could be used to determine the antenna input reactance X. As a practical matter, however, this mathematical formality is usually not necessary. Antennas can often be regarded as lengths of waveguide or transmission line, and this point of view provides a good approximation to the input susceptance or reactance. It's the radiation conductance and radiation resistance that are the real (pun intended) challenge.

CONCLUSION

This article has derived general and powerful new formulas for determining the input conductance (or resistance) for both single antennas and elements in an arbitrarily large antenna array. The formulas avoid the intermediate, and often tedious or impractical, steps of determining self and mutual admittances or impedances. It is necessary only to know the total radiated power and the voltage sources (or current sources).

When the conductance is determined, the susceptance is also determined. Similarly, when resistance is determined, reactance is also determined. This is because they are not independent quantities. They are Hilbert transforms of each other, as are the real and imaginary parts of all physical phenomena. As a practical matter, however, it is usually not necessary to use the formality of the Hilbert transform. For purposes of finding susceptance or reactance, antennas may often be regarded as lengths of transmission line or waveguide. ■

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2. S.J. Mason and H.J. Zimmerman, *Electronic Circuits, Signals and Systems*, Wiley, New York, NY, 1960, p. 351.

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LATEST ELECTROMAGNETIC SIMULATION CONTINUES TO TRANSFORM AND DEFINE MICROWAVE DESIGN

The introduction of three-dimensional (3D) electromagnetic (EM) Simulation launched a revolution in microwave design by allowing engineers to design, analyze and refine 3D microwave components on their computers. For the first time, designers could visualize the electromagnetic fields in their device, understand the device's electrical behavior to an unprecedented degree and build virtual products that work as predicted when manufactured. As EM simulation technology evolves, it continues to transform and define RF and microwave design.

The trend in RF and microwave design is towards the accurate prediction of system-level performance and behavior. Engineers simulate larger and more sophisticated design problems in support of that goal. In antenna design, for example, phased-array antenna system designers are not only simulating the antenna element(s), but also the supporting feed network and active circuits behind the array. Other antenna system designers are focusing on the environment in which the antenna operates—the performance of an antenna beneath a radome, for example, or the interaction of a mobile handset with the body of an automobile. In short, the size and complexity of problems being addressed by electromagnetic simulations have grown enormously.

To enable larger, system-level design, developers of the widely used EM simulator, HFSS, have focused on product features and new technology that deliver even greater accuracy, capacity and performance than before. HFSS

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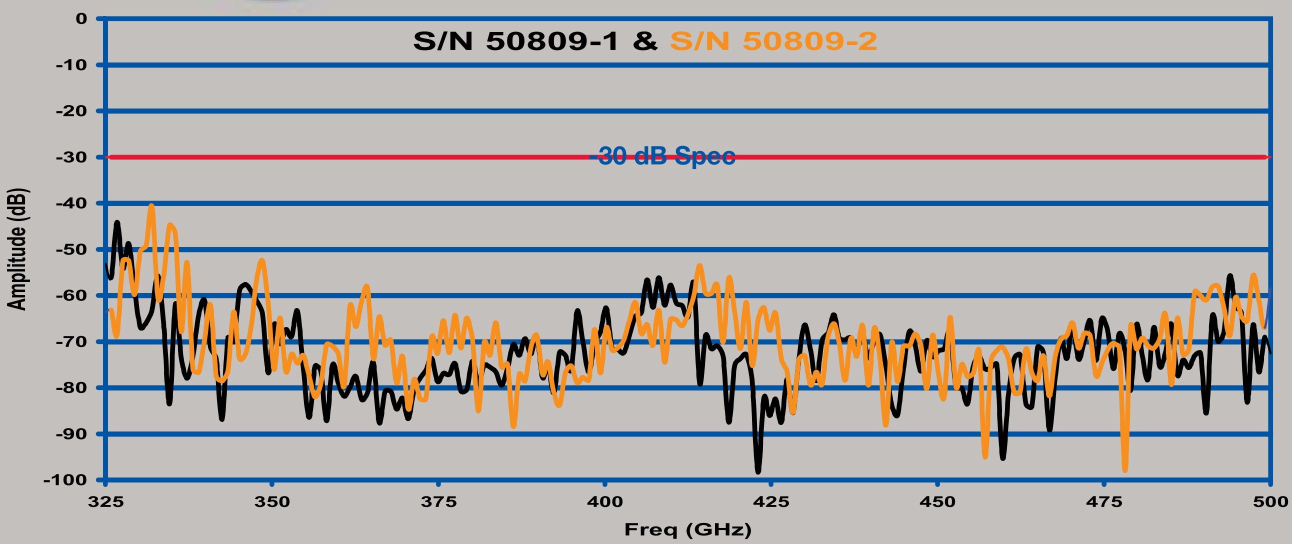

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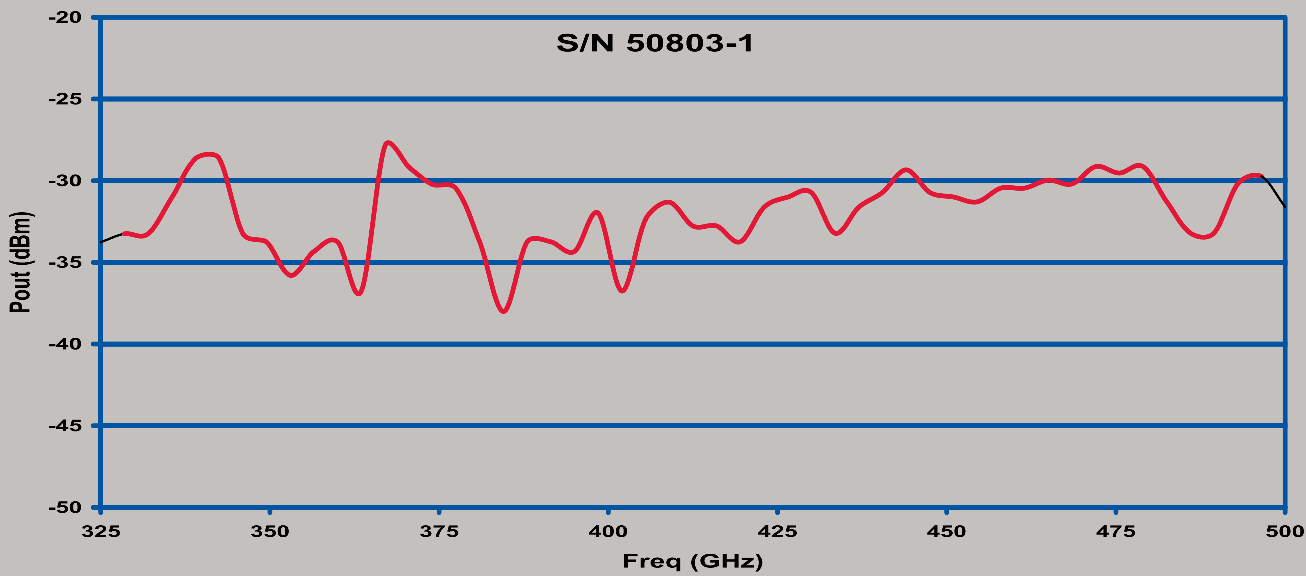
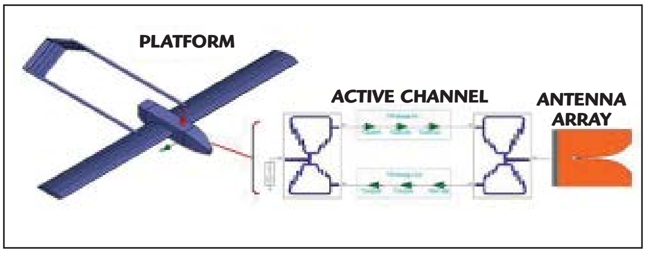


TABLE I

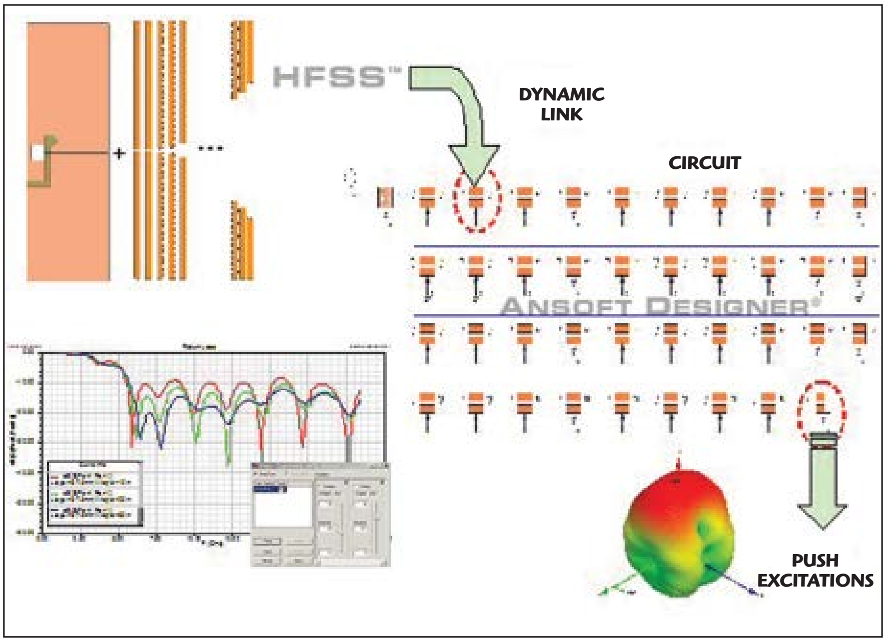
HIGHLIGHTS OF HFSS VERSION 11

Feature	Comment
Higher-order, hierarchical basis functions	accuracy; large volume problems
Iterative solver	lower memory required; multiprocessor
Fault-tolerant, high-quality, finite-element-mesh-generation algorithm	robust meshing of imported CAD; faster solution convergence with fewer passes
Enhanced port solver	faster; greater accuracy
Floquet ports	periodic "space" port for phased arrays and FSS structures
Genetic algorithm optimization	optimization that mimics natural selection
Auto-assign capability for terminals	fast set-up for multi-terminal ports
Automatic Distributed Solve of discrete and interpolating frequency sweeps	leverage compute farms for faster simulation of frequency and parametric sweeps
Distributed Solve for parametric sweeps, sensitivity and statistical analysis	quickly build design and manufacturing data
Refined user interface and dynamic link capabilities	new plotting with templates, scripting, copy/paste

Version 11 includes new higher-order hierarchical basis functions combined with an iterative solver that provides accurate fields using fewer mesh elements. This provides more efficient solutions for large multi-wavelength structures. A new fault-tolerant, high-quality finite-element-meshing algorithm allows HFSS to simulate very complex models two to five times faster using half the memory compared to previous versions. Continued user interface refinement and data linking enables co-design of complex electronic systems. This article discusses some of the new technology in HFSS version 11 (see ***Table 1***) and highlights examples illustrating the new level of speed, accuracy and memory efficiency.



▲ *Fig. 1 Overview of simulation-based design that includes a four-element Vivaldi array antenna placed behind a radome on an aircraft platform.*[1,2]



▲ *Fig. 2 Cascaded network used for Vivaldi taper optimization.*

PHASED-ARRAY ANTENNA ON AIRCRAFT

The following example demonstrates technology specific to HFSS that supports antenna system design. ***Figure 1*** shows an overview of an antenna system and platform installation. The system consists of a four-element Vivaldi antenna array mounted within the radome of a fixed-wing aircraft. The array is fed by active transmit/receive circuits that use traditional microstrip circuit technologies and monolithic microwave integrated circuit (MMIC) low-noise and power amplifiers.

For over a decade, microwave circuits have been designed with distributed transmission-line techniques. Advanced electromagnetic simulators have been used to complement the analysis by providing more detailed physical extraction. However, these traditional approaches have had limitations. Antennas and their operating environments are often 3D and therefore do not have circuit models. New technologies that couple electromagnetic and circuit simulation are extending these traditional techniques to complex 3D structures like the tapered slot (Vivaldi) antenna shown in Figure 1. In addition, these technologies support various system-level analyses—the feed network and antenna array system or the antenna and radome system, for example. In particular, new technologies called Dynamic Link, Pushed Excitations and Data Link enable complex antenna system simulation.

Dynamic Link is a technology that provides bi-directional connection between circuit and electromagnetic simulators. Fully parameterized electromagnetic models are linked to circuits with parameters such as dimensions and material properties passed to the electromagnetic simulator and S-parameter results passed back. Multi-dimensional interpolation between

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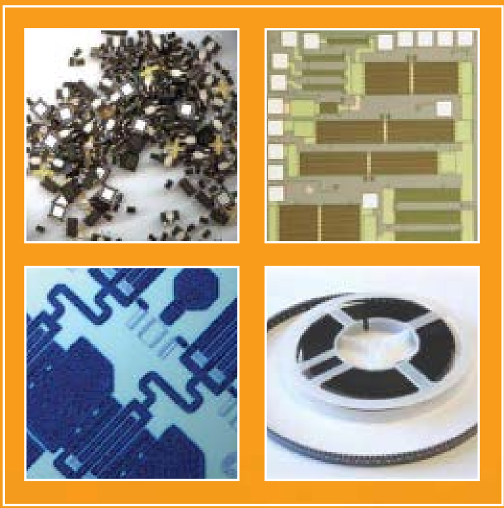

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FMA3025SOT89E

Freq (GHz)	Gain (dB)	S11 (dB)	S22 (dB)	NF (dB)	OIP3 (dBm	P1dB (dBm)	Vcc +6V	Typical Applications
0.3-4	12 to 15	-17	-15	2.1	42	24.0	Id 160mA	• Driver Amplifiers for GSM, CDMA, W-CDMA • CATV/DBS Amplifiers • WiFi/WiMAX/WiBro • Point-to-point Radio Systems • High Linearity Gain Block • This product can be used in TX as well as RX

FMA3067SOT89E

Freq (GHz)	Gain (dB)	S11 (dB)	S22 (dB)	NF (dB)	OIP3 (dBm	P1dB (dBm)	Vcc +6V	Typical Applications
0.8-0.9	18.5	-23.5	-25.5	3.0	40	25.0	Id 170mA	• High Linearity and High Gain Block • GSM, CDMA, W-CDMA Cellular Infrastructure • This product can be used in TX as well as RX
1.8-2.1	16.5	-21	-21	3.2	38	23.0		

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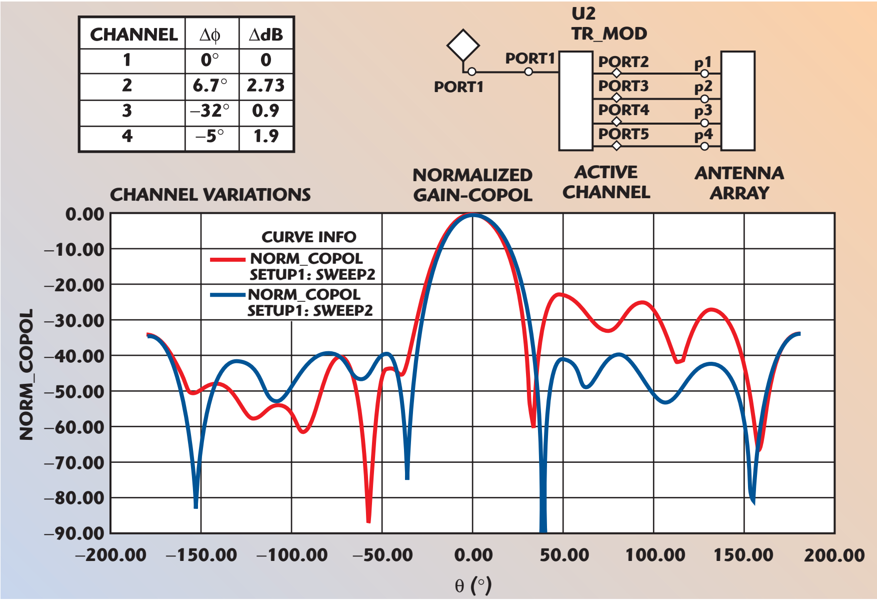
solved dimensions in the electromagnetic models provides the speed of circuit simulation with the accuracy of full-wave electromagnetics.

Pushed Excitations is a technology that closes the loop between circuits and electromagnetics. Circuit simulation produces the voltages and currents on all nodes and all branches of the circuit, respectively. Those voltages and currents can be used as the excitation to the electromagnetic model so that engineers can visualize fields and compute secondary radiation patterns. This can be done without re-solving the finite element problem because Pushed Excitations simply scale the HFSS result by applying the excitations at HFSS ports.

Data Link couples multiple HFSS simulation projects by linking tangential fields on the outer surface of one HFSS project to another. This linkage between projects allows engineers to efficiently simulate very large and complex geometries.

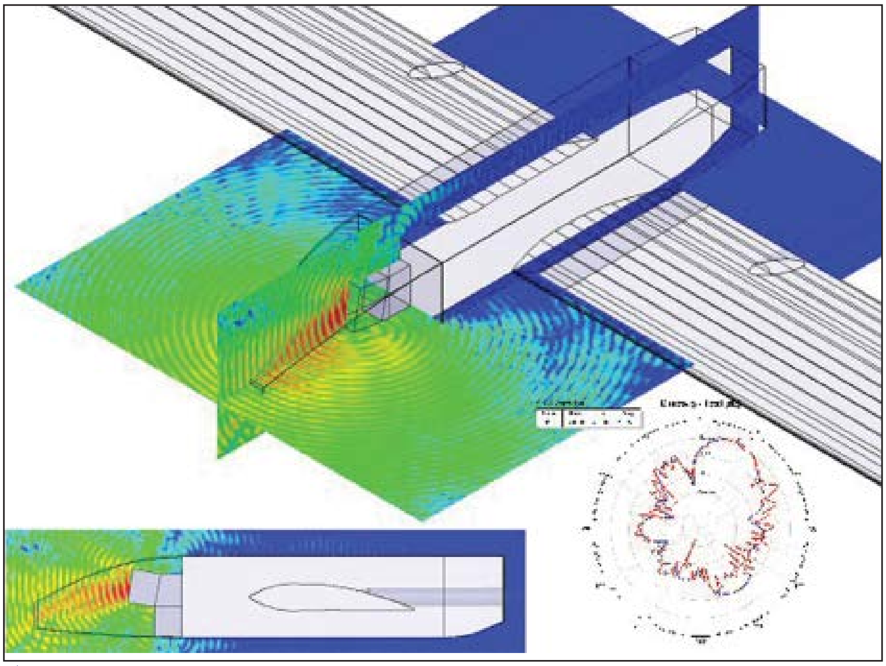


▲ *Fig. 3 Normalized gain for ideal (blue) antenna array and antenna system (red) excitations.*

OPTIMIZING THE TAPERED SLOT PROFILE

Figure 2 illustrates how the Dynamic Link and Pushed Excitations were used to optimize the taper profile of a single Vivaldi antenna element. The project starts by using HFSS's unique capability to create frequency dependent circuit models of arbitrary geometries. By combining these models with a distributed parametric sweep of selected variables and dynamically linking to the circuit, "tunable" distributed circuit models can be realized. Once the dynamically linked, slot-line compo-

nents are cascaded in circuit, the simulation achieves the accuracy of 3D electromagnetics with the speed of circuit simulation. Through real-time tuning of the circuit with subsequent feedback from HFSS, the optimal taper profile was identified. With the optimal taper profile, circuit excitations are pushed to the HFSS model so that the resulting far field patterns, shown at the bottom of Figure 2, may be visualized.

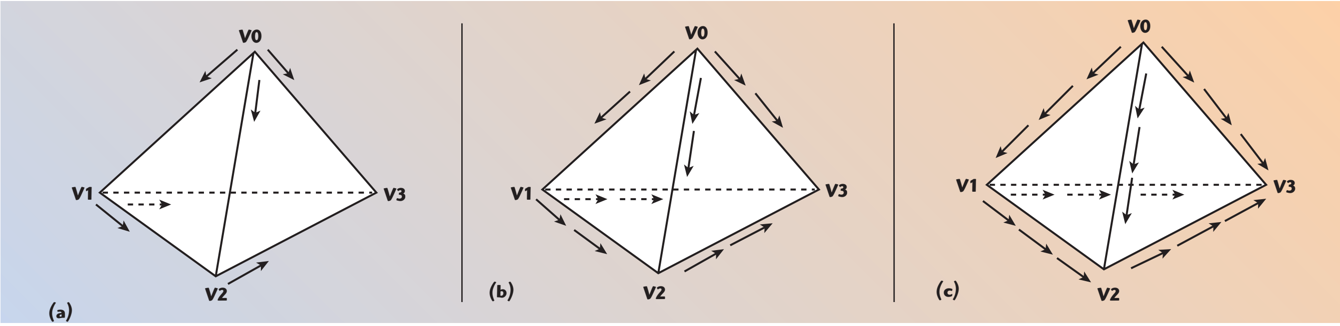


▲ *Fig. 4 Phased-array antenna with feed network on aircraft uses Dynamic Link, Pushed Excitations and Data Link to couple electromagnetics with circuits.*

TESTING THE ARRAY AND FEED NETWORK

Using the optimized Vivaldi element, a 1 × 4 linear array is assembled and extracted in HFSS. To simulate system performance, the antenna array is dynamically linked to the active circuit network. In addition to the base excitations required for normal incidence, one test employed phase and amplitude variations to simulate the effects of manufacturing tolerances. Pushed excitations were used to visualize and predict the antenna system's performance under the various test conditions. ***Figure 3*** shows the "variation" test case (red) versus the ideal normal incidence case (blue) where no variation in amplitude or phasing was employed. As shown in the figure, the result of the manufacturing tolerances was an increase in side lobe levels.

The final validation of the system is obtained by installing the antenna



▲ *Fig. 5 Tetrahedral element used in HFSS represents fields at vertices, edges and faces.*

array and feed network on an unmanned, fixed wing platform. Here, all three technologies were used to simulate the phased array with the active circuits adjusted to achieve a 22° beam scan. The resulting currents and voltages were pushed to the terminals of the antenna to determine the radiated fields, which included the effect of the feed circuitry. Finally, the Data Link technology is used to compute the fields of this antenna when placed beneath a radome on an aircraft, as shown in ***Figure 4***. As can be seen in the figure, the calculated fields produced inside and outside the radome are consistent with a 22° beam scan.

ADVANCED TECHNOLOGY IN HFSS

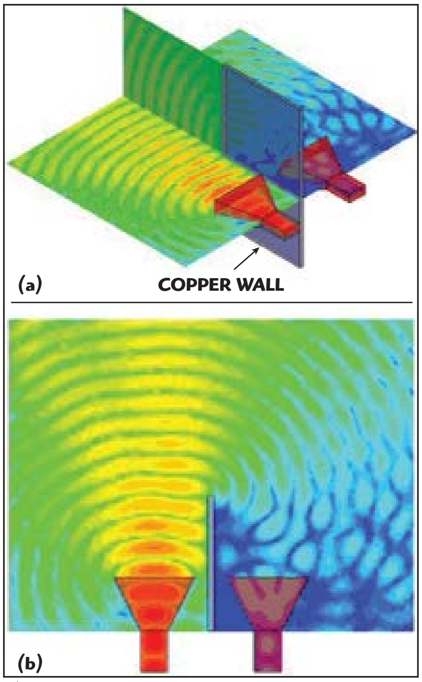
The previous phased array example was solved using HFSS Version 11 and leveraged new solver technology to allow the large simulations. Some of these technologies will now be discussed, including higher-order hierarchical basis functions, iterative solver, and the finite-element-meshing algorithm that allows HFSS to simulate bigger and more complex geometries.

HIERARCHICAL BASIS

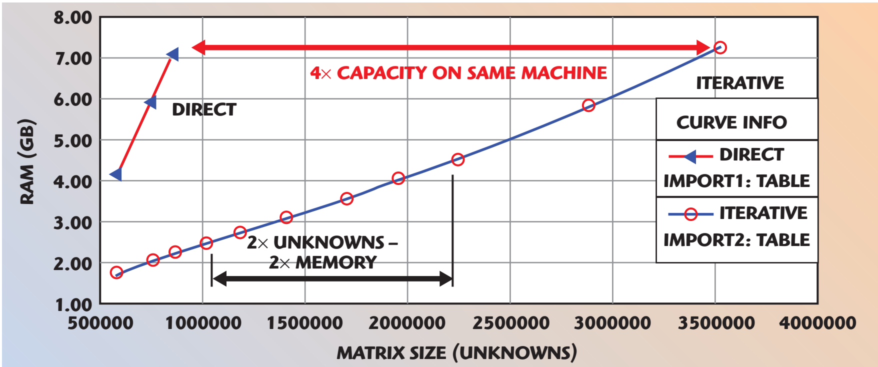
The finite-element method as implemented in HFSS works by dividing a 3D problem space into tetrahedral-shaped elements. The electric field in each of these tetrahedrons can be interpolated from the values associated with the edges, faces and volume of the tetrahedron. HFSS stores the components of the field that are tangential to the six edges and four faces of the tetrahedron. In addition, HFSS can store the vector components of the field within the volume of the tetrahedron. The field inside each tetrahedron is interpolated from these values.

Various interpolation schemes, or basis functions, can be used to interpolate field values from the nodal values shown in ***Figure 5***. Zero-order tangential elements have six unknowns per tetrahedron. A zero-order basis function assumes that the tangential component of the field is constant along each edge. First-order tangential elements have 20 unknowns per tetrahedron. Twelve of these unknowns arise from assuming that the tangential component of the first-order tangential element basis function is linear along each edge. The remaining eight unknowns are added to ensure completeness of the polynomial and are normal to the edges but tangential to the faces. Second-order tangential element basis functions have 45 unknowns including 18 unknowns associated with the edges, 24 unknowns associated with the faces and three unknowns associated with the volume.

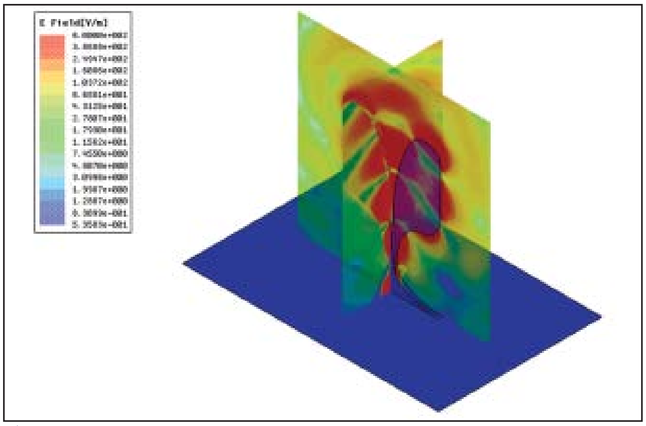
HFSS by default uses first-order elements as these have proved to be the most efficient with general problems. Users of previous versions of HFSS may be familiar with an option within the solution setup panels that allowed



▲ *Fig. 6 Two pyramidal horn antennas in presence of a conducting wall simulating co-site coupling illustrates performance improvement of iterative solver.*



▲ *Fig. 7 Comparison of direct vs. iterative solver shows a 4× reduction in RAM and near linear memory usage growth vs. number of unknowns.*



▲ *Fig. 8 Vivaldi antenna solved 6.7 times faster using 2.7 times less memory due to advanced meshing in HFSS Version 11.*

them to select "low order" as the solution basis. This feature was useful especially for signal integrity problems such as connectors and printed-circuit escape routing where geometric detail in the model forces a dense finite-element mesh. In these cases, the mesh is denser than required for accurate field prediction; hence, using a low-order (zero) element reduces the total number of unknowns and speeds the solution while maintaining accuracy. With Version 11, there is now the additional option of selecting a second-order element. Second-order elements are useful for geometries containing large homogeneous regions that can be represented by large tetrahedrons using higher-order interpolation.

ITERATIVE SOLVER

Working hand-in-hand with the hierarchical basis is a new iterative solver. The finite-element formulation produces a matrix equation that must be solved to find the unknown electric field values within the elements. This matrix is sparse because of the local interaction between tetrahedrons. The most memory efficient method for solving a sparse matrix equation is to use an iterative solver (as compared to the more traditional direct-matrix solver). The iterative solver has the advantage of lower memory requirements and faster solutions as long as the process is conditioned properly. HFSS Version 11 uses solutions from lower-order elements to precondition the iterative solver for higher-order elements. Indeed, it is this unique coupling between the hierarchical bases and the matrix solver that makes the iterative procedure practical, reliable and fast.

The memory savings benefit of the new matrix solver is made evident by the example demonstrated in ***Figure 6***. Here, two pyramidal horn antennas in the presence of a conducting wall simulates co-site coupling. The geometry is a large 447-cubic-wavelength volume of a homogenous vacuum medium. The simulation was performed using a direct solver and again with Version 11 using the iterative solver. Both solvers converged in three passes; however, the iterative solver required 3.2 times less RAM and was 6.4 times faster than the direct solver.

A further experiment was performed to examine growth of the memory requirements as the number of unknowns is increased. The convergence criterion delta-S was set ex-

tremely small to force the number of unknowns to grow to the limits of the memory capacity of the computer. The graph in ***Figure 7*** shows the memory usage of the direct and iterative solvers versus the number of tetrahedrons for each pass. The graph may be interpreted in two different ways. First, for a fixed number of tetrahedrons, the iterative solver uses roughly four times less RAM. In fact, HFSS memory usage is approaching a theoretical minimum because memory usage grows linearly, that is, it doubles with a doubling of the number of unknowns. Alternatively, a second interpretation is that HFSS can solve larger and more complex problems with a fixed amount of computer RAM (6 GB, for example).

MESHING ENGINE

Version 11 has a new meshing engine that has significant impact on the solution process, speed and memory usage. Many applications require importation of geometries from other computer aided design (CAD) programs. The fault-tolerant meshing engine automatically detects and repairs structural problems with these geometries and optionally allows the user to remove unnecessary details such as chamfers, bends and drill holes.

The new engine creates a higher-quality mesh with well-formed tetrahedrons. The higher-quality mesh combined with further improvements in mesh refinement has resulted in faster convergence for most simulations. HFSS Version 11 often converges with fewer adaptive passes and hence requires less RAM and CPU time. The example of a Vivaldi antenna in ***Figure 8*** illustrates this new performance. The older version required 13 adaptive passes, 2.67 GB RAM and just over 20 minutes to solve. Version 11 only required nine passes, 770 MB RAM and only three minutes to solve. That's a 6.7 times faster simulation and 2.7 times lower memory requirement.

CONCLUSION

The need for engineers to solve larger and more complex geometries efficiently is of growing concern. HFSS Version 11 has new features and technologies that provide an engineering solution to address this concern. The combination of a new hierarchical basis, iterative solver and advanced meshing engine push the frontier of electromagnetic simulation. Linking circuits and electromagnetics with features like Dynamic Link, Pushed Excitations and Data Link allows engineers to design and validate entire end-to-end systems before undertaking prototype production.

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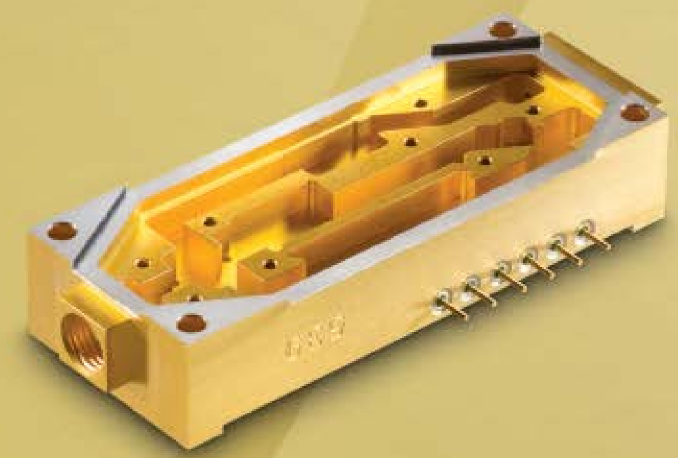
A TRUE SYNTHETIC TEST ENVIRONMENT

Today's test and measurement suppliers face ever-increasing pressure to deliver more cost-effective solutions to users. They strive for higher production rates while producing products with greater complexity. They are therefore being challenged to supply flexible, scalable and efficient test systems that solve these problems. Synthetic instruments that "synthesize" the stimulus or measurement capabilities found in traditional instruments through a combination of software algorithms and hardware modules that are based on core instrumentation circuit building blocks are a promising solution.

In order to deliver the promised flexibility and modularity of synthetic test systems, Aeroflex has developed the Synthetic Multi-function Adaptable Reconfigurable Test Environment—SMART^E™ 5000 Series—a synthetic test environment that encompasses hardware, software, test practices and support required by users for a complete test solution. This synthetic test system provides a highly integrated, complete-solution environment and includes configurable modules encompassing the best hardware to solve test challenges.

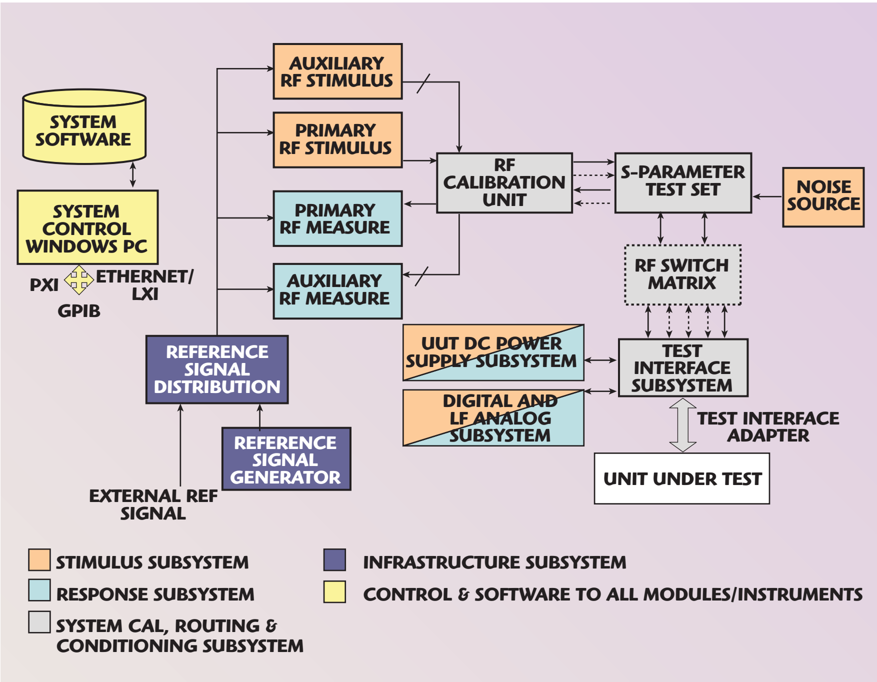
A synthetic test system utilizes multi-functional stimulus and response measurement hardware channels tightly coupled with digital signal processing software (rather than a collection of dedicated-function instruments) to generate signals and perform measurements. Synthetic test environments offer low total cost of test, greater throughput and typically take less than half the rack space and weight of conventional discrete instrument-based systems.

AEROFLEX TEST SOLUTIONS,
INSTRUMENTS DIVISION
Stevenage, UK

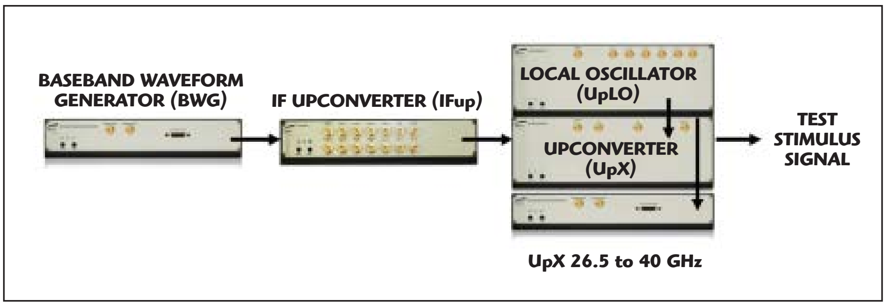


The new system is based upon the fifth generation evolution of the company's synthetic test technology, which meets the high throughput, high-performance test requirements for radar applications, satellite payloads and transmit/receive modules and subsystems for phased-array radar antennas. In this fifth generation, the proprietary synthetic-test chassis has evolved into commercial off-the-shelf (COTS) LXI modules that support multiple vendors and multiple industry standard platforms (LXI, PXI, cPCI, GPIB).

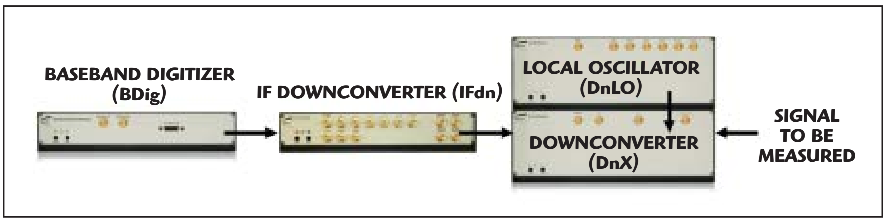
SMART^E's configurability enables systems to be properly scaled in terms of size, function and cost for manufacturing, flight line, and depot test for military prime equipment test solutions. The environment also features system declassification of embedded facilities now mandated for most military systems. Modularity and multi-vendor component and subsystem support, along with the ability of synthetic subsystems to adapt to new requirements via software, give users obsolescence protection.



▲ *Fig. 1 Generic block diagram of a SMART^E 5000 environment test solution.*



▲ *Fig. 2 Components of an LXI version of a SMART^E RF/microwave stimulus channel.*



▲ *Fig. 3 SMART^E 5000 RF/microwave response subsystem.*

This environment is provided using COTS system components to ensure that users have a competitive test solution best matched to their requirements. Furthermore, the extensive application of industry standards in the composition of the environment ensures that test solutions will fit well into the user's operating environment. Moreover, the user likely will be more familiar with a COTS-based implementation over a proprietary one.

INDUSTRY STANDARD FOUNDATIONS

A key to the flexibility of SMART^E is its foundation of industry standard software, including Windows, C/C++/C# and National Instruments' TestStand. The open architecture combination of both industry standard software and hardware enables multifunctional extensions that can be easily implemented.

An extensive test library, with built-in test personality customization via user-settable/exposed parameters, results in rapid start-up for new applications. The test environment embodies all of the calibration, verification, diagnostics and test practices needed to achieve its specifications, which are given at the system level, rather than simply as a collection of instrument specifications that must be analyzed and then extrapolated to the system level.

This focus at the system level includes a multi-tiered calibration practice based on calibrating procedures required for very few, basic transfer standards without the need to remove and calibrate each individual synthetic module or each separate subsystem. Calibration encompasses full National Institute of Standards and Technology (NIST) traceability. All systems are designed to enable system verification tests, even with a unit under test already connected to the environment and ready for testing. Each system also provides simulation software that enables test programs to be run off-line from the system hardware, while still being able to step through all the test sequence elements as if hardware were connected.

From a key subsystem perspective, the systems are constructed of the following building blocks: stimulus,

response measurement, system calibration, signal routing and signal conditioning, system controller and software as well as a system infrastructure subsystem. ***Figure 1*** shows the generic block diagram of a SMART^E 5000 environment test solution

CONFIGURING TEST HARDWARE

Test requirements come in a seemingly endless variety. The one constant is that the test environment should be applications driven and able to deliver the specific levels of performance required. Devices to be tested dictate the number of simultaneous stimulus signals and the range of frequency, power and modulation of the stimulus signals required.

The specifications and test strategy dictate the measurements and therefore the measurement instruments required in terms of both function and performance. The combination of the DUT test signal requirements and the characteristics of the measurement instruments dictate the calibration and signal routing and conditioning components of the system.

STIMULUS SUBSYSTEM

A stimulus subsystem can encompass a wide variety of combinations of digital, analogue and RF/microwave "channels." Digital and analogue capability is typically provided in PXI/cPCI form factor, RF and microwave functionality in PXI or LXI form factor. However, conventional rack-mounted instruments may also be utilized in cases where they provide the best match to the measurement problem, though usually not the best modularity of implementation. ***Figure 2*** shows the components of an LXI version of a SMART^E RF/microwave stimulus channel.

RESPONSE MEASUREMENT SUBSYSTEM

Like the stimulus subsystem, the response measurement subsystem of a SMART^E can encompass a wide variety of mixed-signal capabilities from DC to microwave. As for the stimulus subsystem, system module components in PXI/cPCI, LXI or discrete instrument form factor may all be utilized in concert. ***Figure 3*** shows the SMART^E 5000 RF/microwave response subsystem

Common modular instrumentation capability is available off the shelf for digital multi-meters, digital sampling oscilloscopes, arbitrary waveform generators, digital IO and a variety of other measurement functions. PXI/cPCI and LXI and response measurement subsystems may each consist of one or more channels, which may be optionally configured for tuning speed, power level and frequency range. These include UUT interface subsystems, UUT power supplies, system infrastructure, digital IO subsystems and industry standard PXI synthetic instrumentation modules.

CALIBRATION

In the deployment of synthetic microwave test systems, Aeroflex has engineered a very specific hierarchical calibration strategy involving three distinct levels of calibration: primary calibration, operational-reference-plane-origin calibration and extended-reference-plane calibration. This hierarchy is specifically designed to minimize the overhead and maximize the convenience of calibration and verification on a system level basis.

Primary calibration is related to the components of the system responsible for establishing the most fundamental stimulus and measurement parametric behavior of the system. The RF/microwave elements of the system include the reference frequency generator, noise source, power meter and power sensors, S-parameter calibration kits and a core calibration resource known as the Local Calibration Unit (LCU).

For low-frequency stimulus, a high-performance PXI DMM may be the primary reference standard, easily removed for periodic calibration. The LCU facilitates the second level in the calibration hierarchy for RF/microwave signaling. It is the point at which all system resources are integrated to provide a fundamental reference plane origin for both RF/microwave stimulus and response signaling. The LCU provides signal multiplexing to DUT test ports and to industry standard NIST traceable power calibration instruments.

SYSTEM INFRASTRUCTURE COMPONENTS

System infrastructure components refer to components generally required to make the various individual subsystems operate as an integrated environment. In some instances, these may be provided by the user's application environment. The SMART^E 5000 family provides for required or optional infrastructure components such as an LXI module sub-rack, system racks with AC power infrastructure including uninterruptible power supply, cooling, EMI shielding, system reference signal generation and distribution modules, LO distribution modules, system interconnect cable assemblies, LAN interface router and UUT interfaces.

Test capability can be configured to match the test problem to be solved and the environment also enables expansion or reconfiguration of a system to meet new requirements, providing test resource investment longevity and significant immunity from obsolescence.

SMART^E SPECIFICATIONS

Reflecting its RF/microwave-centric test perspective, the SMART^E features synthetic stimulus and measurement channels to 40 GHz in configurable modular bands with two synthetic channels as standard, one for stimulus and one for measurement, extendable to multiple parallel stimulus and multiple parallel response synthetic or non-synthetic channels. A highly configurable baseband encompasses cooperative narrow and broad bandwidth capabilities and includes very fast tuning or lower speed/reduced cost local oscillator options with AM, FM, PM and arbitrary modulations.

Also featured are standard power settings and a measurement range of –90 to +10 dBm to better than 0.1 dB resolution, extendable via standard and custom power amplifier options. Standard and customer-specified switch matrix subsystems and interface panels are supported. The system provides continuous wave and pulsed measurements—S-parameters, envelope, peak and average power, spectral, noise figure and modulation/demodulation—with network analyzer comparable uncertainties at high throughput measurement rates.

The test environment is application-specific for satellite payloads, phased-array T/R modules and subsystems/assemblies, and multi-device under test military ATE platforms, as well as specific military-tester/ATE implementations for EW and radar range applications. Specialized tactical air navigation (TACAN), identification friend or foe (IFF), CNI and ATE subsystems as well as phase-noise test subsystems are available as system options.

The SMART^E 5000 test environment provides for mixed-signal testing (including DC response), digital input/output (I/O) up to 400 MHz at double data rate (DDR) and low voltage differential signaling (LVDS) with programmable levels up to 100 MHz, low frequency analogue stimulus and measurement from a broad selection of modular or conventional instruments including arbitrary waveform generators (AWG) at gigahertz sample rates digitizers up to multi-gigahertz sample rates, and defense wavelength division multiplexing with variable sample rates up to 1.8 GS/s.

CONCLUSION

SMART^E 5000 test environments are scaleable in performance and function, ideal for implementing configurable and reconfigurable systems that provide flexibility and resistance to obsolescence, and are a vast improvement on historical rack and stack test solutions. A single synthetic stimulus and measurement channel pair can perform the tests that traditionally require multiple standalone instruments. Thus, there are savings in size and weight requirements for a complete microwave test solution. The result is a unique, state-of-the-art, synthetic, and mixed-signal RF and microwave test environment.

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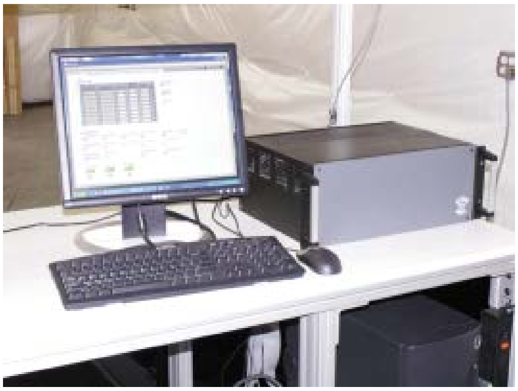


A PORTABLE PULSED-IF RCS MEASUREMENT SYSTEM

Emerging radar cross section (RCS) measurement needs are making it increasingly necessary to take the measurement system to the target, rather than take the target to a fixed measurement site. With this in mind, QuarterBranch Technologies Inc. set out to build the first truly portable pulsed-IF RCS measurement system without sacrificing capabilities that most users require. The result is RadarMan, with a core unit that can attain measurement speeds rivaling the practical limits of other systems, with equal measurement sensitivity.

Real-time plotting capabilities are extensive, including near real-time inverse synthetic-aperture radar (ISAR) and SAR imaging. In addition to the real-time plotting package, each RadarMan system includes a single-seat license of QuarterBranch's offline processing/plotting package, Data Display.

RadarMan is a compact, lightweight, pulsed-IF radar system that is engineered to be cost-effective, highly reliable and supportable at a level not achievable in other mainstream RCS measurement systems. These key attributes revolve around the remarkably unique architecture and physical package of the product in contrast to other pulsed-IF acquisition systems. Specifically, all of RadarMan's core functions, including all digital control, data and timing circuitry, IF circuitry, a frequency-agile synthesizer, and all frequency up- and down-conversion are contained in a single seven-inch tall box that weighs approximately 25 pounds.

SPECIFICATIONS SUMMARY

RadarMan operates at frequencies from 2 to 18 GHz, with optional frequency expansion down to 100 MHz. It has 10 kHz frequency resolution and a frequency switching speed of less than 5 µs. The frequency table allows full polarization matrix operation. Up to eight waveform table entries (chirps) can contain 1 to 8192 steps, with up to 65,536 coherent integrations in increments of powers of two. The system can be placed in any of a number of diagnostic loop modes, including IF, RF converter, low-power transmit drive and HPA. Any one of these loops can be configured as a "fast loop" to be included within a target col-

QUARTERBRANCH TECHNOLOGIES INC.
Lovettsville, VA

lection run for monitoring system stability.

RadarMan has a selection of two video bandwidths, 100 and 250 MHz. A/D conversion is 14 bits each for the I and Q video channels. Instantaneous dynamic range is 65 dB.

The system supports pulse repetition frequencies (PRF) ranging from 3 kHz to 2 MHz. Range delay can be set from 0 to just under 328 µs in 1 ns steps, and pulse widths can range from 5 ns to 2 µs, also in 1 ns increments. All timing parameters as well as transmit drive levels are adjustable on a band/sub-band basis.

The IF module contains a phase modulator that allows 16-state polyphase operation to correct for I/Q circularity errors, as well as for ambiguous clutter suppression. Phase agility operates in a number of selectable sequences. These sequences include: fixed phase (at any of the 16 phase states), biphase, complementary, incremental and pseudo-noise (PN). For each setting of coherent integrations, the start value of the PN sequence can be set by the user to optimize the multiple-time-around suppression for specific range conditions. In addition to the built-in phase sequences, the user can execute a custom phase sequence by creating a simple ASCII format file.

USER INTERFACE SOFTWARE

The user interface software allows for full control of all radar hardware parameters, data collection and storage and real-time data processing/display. This intuitive program also features integrated target/antenna motion control, simple calibration and background subtraction reference collection, an image parameter calculator and range walk with real-time transmit/receive bracket adjustments. Measurement parameter setups can be saved and recalled, as well as calibration and background subtraction reference vectors.

Plot types include line plots (magnitude or phase vs. frequency, FFT-based range profiles, or Doppler plots, for example), time/position charts, intensity charts (magnitude/phase vs. frequency/range/Doppler vs. time) and ISAR or SAR images. For each plot type, the user can select the desired X- Y- and Z-axis data sources from a plot type-specific list for each plot axis. The user may dynamically enable or disable processing functions such as calibration, background subtraction, R^4 correction, weighting function and zero-Doppler subtraction as data is collected. Scaling for all plot axes can be either auto-scaled or adjusted manually.

The software includes a series of automated system diagnostics tests. These tests include A/D statistics, long-term system stability using loop mode tests, receiver linearity and I/Q circularity.

DATA DISPLAY OFFLINE PROCESSING SOFTWARE

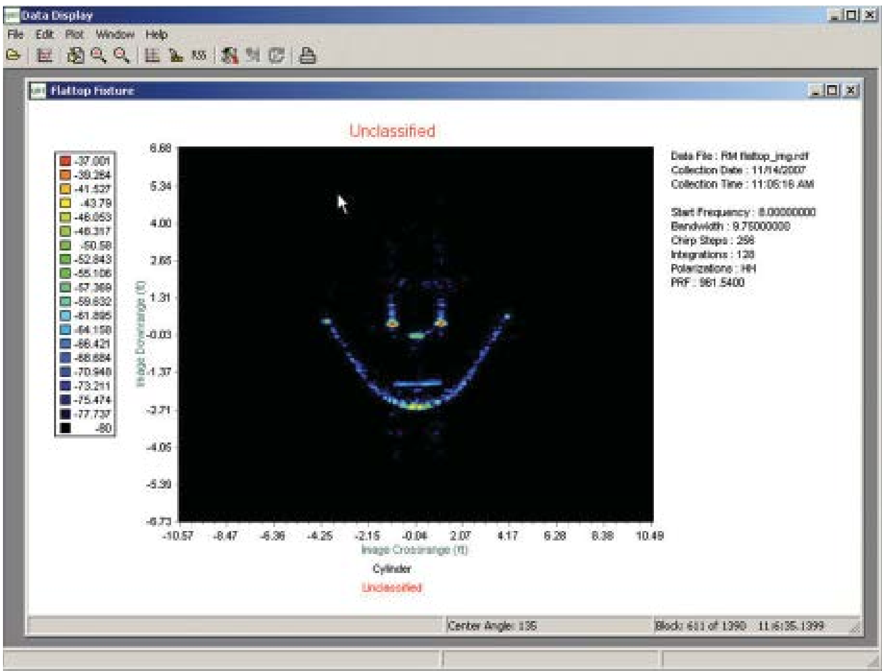
Data Display is a full-featured RCS processing package for offline processing and plotting of RadarMan data (see ***Figure 1***). A single-seat license of Data Display is included with the purchase of each RadarMan unit. Additional licenses can also be purchased or leased.

The user interface for Data Display, like that for RadarMan, is very intuitive to use. The processing setup screen contains a section for selecting data files, and a section for selecting plot types, processing functions and plotting parameters. An error check feature assures that all selections can be logically processed and displayed. The processing setup can be saved as a named file for later use. Once the processing setup is complete, the setup page is exited and the plot windows open. Pressing the Begin Processing button starts the processing engine to create the data plots.

The software allows re-plotting of RadarMan data in all formats available in its real-time plotting, with the additional capability of navigating through files to any point based on block number, time stamp, or target/antenna position. In addition, the software can simultaneously plot data from multiple files or multiple waveform entries, either as overplots in a single window, or individually. Markers on line plots display the X and Y values at the location of the marker, and plots can be easily zoomed to any scale.

ISAR images can be created at any requested angle, or continuously updated at requested angle increments. These image sequences can be saved to .AVI files as movies at selectable frame rates. In addition to ISAR images, the software can create SAR images from data collected on a rail-mounted antenna connected to RadarMan.

Displayed images can be measured on individual pixels using a cursor tip tool, or regions of the image can be selected using a rectangle drawing tool to display the RSS value of the included pixels. The software also performs image edit and reconstruct (IER) for ISAR images, as well as sector statistics for line plots.



▲ *Fig. 1 A typical Data Display plot.*

QuarterBranch's policy for adding processing functionality to Data Display is that if the requested feature is added to the standard product for release to the entire user population, the new feature is added at no charge. If the feature is to be proprietary, then standard time-and-materials charges apply. All requests for additions are placed into the release schedule to ensure timely availability for all customers who are under warranty or paid support. Added features that are proprietary to a user are not made available in the standard product and are not released to the general user population. In short, if Data Display does not have a required tool, just ask.

SUPPORTABILITY

The incredibly small size and relatively low price of the RadarMan core product allows it to be supported in its entirety through the deployment of an on-site spare unit. For critical operations where down time cannot be tolerated, this approach ensures virtually 100 percent system availability by direct replacement of the entire RadarMan core unit in the event of a failure, which can be completed in less than 10 minutes. With this level of support, the original system can be sent for repair while operations continue using the spare unit.

For less critical applications that cannot justify the purchase of a spare core unit, quick-reaction return-to-operation support can still be obtained through short-term spare rentals, which can be shipped overnight for immediate installation.

Unit-level support also makes system upgrades more tolerable as technology progresses. For this effort, a spare unit would be deployed while the original is updated with the new version, thus eliminating down time during the upgrade process.

FLEXIBILITY

RadarMan is adaptable to virtually any required measurement configuration including multiple antenna bands, full-polarization matrix switching and dual receive channels. It is designed to interface to any appropriate transmitter device as required for the application, from solid-state milliwatts to kilowatts from TWTAs. Its features and specifications make it fully capable of instrumenting large, fixed ranges, while its size makes it ideal for portable field measurements, from ground-based operations such as flight-line or production-environment measurements, to airborne applications.

CONCLUSION

Though it comes in a remarkably small package, RadarMan is just as remarkably capable. Smart design decisions left out seldom-used legacy features, such as multi-decade video bandwidth selection and million-step-deep waveform tables that are typical in competing products, enabling the system to be small and relatively easy to use, while supporting the vast majority of measurement requirements.

QuarterBranch Technologies Inc., Lovettsville, VA (540) 822-4634, www.quarterbranch.com.

RS No. 302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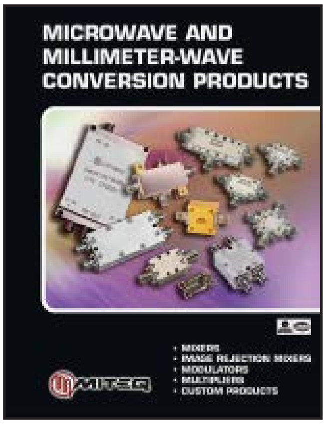
CONNECTION

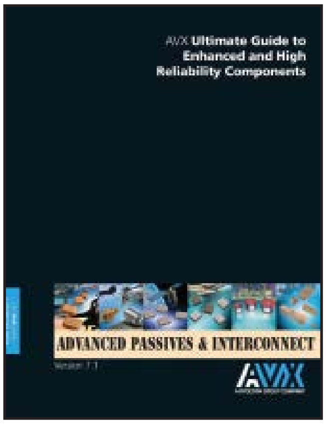


Microwave and Millimeter-wave Conversion Products

MITEQ's 515-page Microwave and Millimeter-wave Conversion Products Catalog features the company's latest state-of-the-art mixers, image rejection mixers, modulators, multipliers and custom products. This detailed engineering reference manual features product specification sheets including typical test data, outline drawings, questions and answers, technical applications and notes.

MITEQ
Hauppauge, NY (631) 436-7400, www.miteq.com

RS No. 310



Rugged-devices Catalog

AVX's high-reliability catalog highlights the company's wide range of products specifically designed for defense, aerospace and space applications. The catalog showcases AVX's comprehensive range of rugged, military qualified products including ceramic capacitors, resistors, filters, integrated passive components, timing devices, module devices and connectors, which are well suited for harsh environments.

AVX Corp.
Myrtle Beach, SC (843) 448-9411, www.avx.com

RS No. 311

Product Selection Guide

Hittite Microwave's Product Selection Guide summarizes over 625 products, including 105 new products. Also featured are Hittite's newly acquired Velocium advanced GaAs MMIC products covering DC to 86 GHz. The addition of the Velocium product line expands Hittite's product offerings for automotive radar, long and short haul communications, fiber optics, test equipment, radar imaging, space and military applications.

Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3373, www.hittite.com

RS No. 312

Online RF Products Catalog

JFW Industries has launched its new E-Store, an online guide to the company's most popular RF products. Product categories include fixed attenuators, terminations, manual variable attenuators, RF coaxial switches, power dividers/combiners and impedance matching. Users can search for products by keyword, name, or by browsing the illustrated, hyperlinked web pages.

JFW Industries Inc.
Indianapolis, IN (317) 887-1340, www.jfwindustries.com

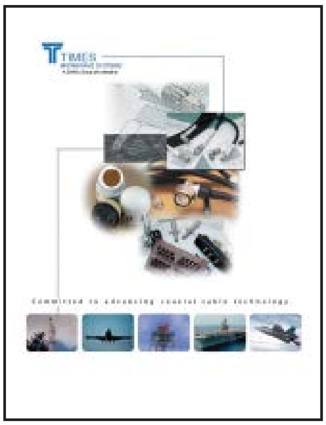
RS No. 313

RF and Microwave Products Catalog

The new catalog from Aeroflex/Weinschel outlines a wide range of RF, wireless and microwave components and subsystems. Product lines include programmable step attenuators (PIN, FET, relay and edgeline technologies), resistive power splitters, dividers, high-power (up to 1000 W) and low passive IM fixed attenuators, coaxial terminations, continuously variable and manual step attenuators, Planar Blind-mate and Planar Crown connector systems, and custom and RF simulation subsystems.

Aeroflex Inc.
Plainview, NY (516) 694-6700, www.aeroflex.com

RS No. 314



Products and Capabilities Brochure

Times Microwave Systems has recently published a new capabilities brochure giving an overview of the company's history in microwave and RF transmission lines and the range of resources and products that the company offers. Technologies include low-loss, closed cell foam polyethylene dielectric, taped expanded PTFE dielectric coaxial cables, hermetically sealed cable assemblies, low smoke cables for shipboard use and high frequency multi-port interconnection systems.

Times Microwave Systems
Wallingford, CT (203) 949-8400, www.timesmicrowave.com

RS No. 315


TRAK
Mission-Critical Solutions
Ferrite Assemblies for
Phased Array Applications
Electronic Warfare
Homeland Security
Radar
C4ISR
Space
Low Profile
Microstrip
Isolators/Circulators
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• <1gm Mass
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• 3 - 38 GHz Heritage
Compact Duplexing
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Dual Circulator
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• Peak Power >10 kw
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sales@trak.com
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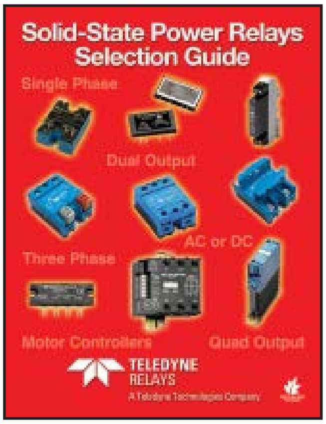
use RS# 146 at www.mwjournal.com/info

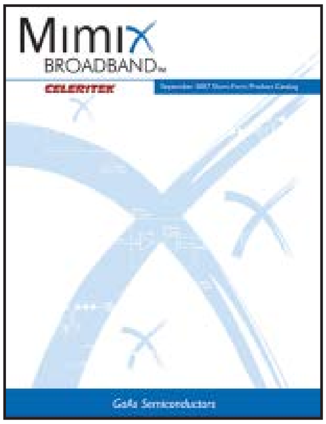


Power Relays Selection Guide

Teledyne Relays introduced its new Solid-state Power Relays Selection Guide for industrial/commercial applications. The catalog features 40 families of solid-state relays and motor controllers in an easy-to-use format to quickly help designers choose a product. The 24-page digest provides detailed information about the many packaging configurations available from Teledyne Relays for AC and DC switching.

Teledyne Relays
Hawthorne, CA (800) 284-7007, www.teledynerelays.com

RS No. 316

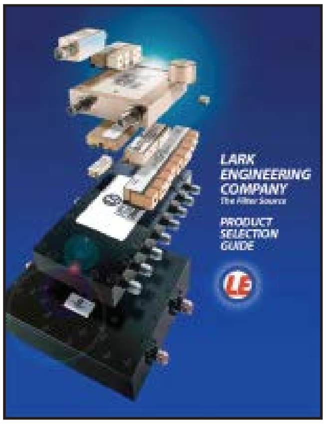


RF Catalog and CD-ROM

Mimix Broadband's updated short-form print catalog and full product catalog on CD-ROM include new product highlights, updated datasheets with more comprehensive information and measurement curves, RoHS program information, application features and notes, company and facility overviews, ordering information and a complete listing of international sales representative and distribution networks.

Mimix Broadband Inc.
Houston, TX (281) 988-4600, www.mimixbroadband.com

RS No. 317



Filter Products Selection Guide

Lark Engineering's new Product Selection Guide highlights the company's wide range of filter products, including its new Switch Filter Systems. An eight-page short form catalog features a user friendly, quick reference to filter specifications and capabilities that guides users to the filter ideally suited for the application. For specifications and performance simulations, users are directed to a filter design tool located on Lark's web site.

Lark Engineering
San Juan Capistrano, CA (949) 240-1233,
www.larkengineering.com

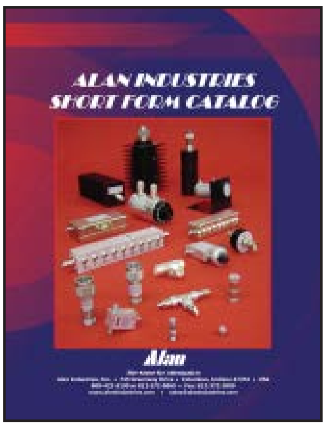
RS No. 318

LTE Technical Overview

A 20-page, full-color technical overview from Agilent provides an overview of Long Term Evolution (LTE) and demonstrates how the company's solutions can help the reader introduce LTE 3GPP devices and products. Topics covered include an overview of the technology, a discussion of the physical layer as well as in-depth information on designing LTE systems and circuits, generating LTE signals and performing LTE signal analysis. Several detailed technical diagrams help to further explain this technology.

Agilent Technologies Inc.
Santa Clara, CA (877) 424-4536, www.agilent.com

RS No. 319

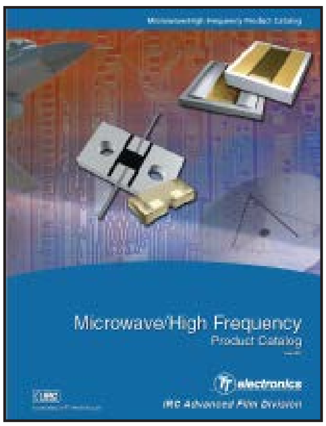


Components Catalog

Alan Industries' new Short Form Catalog features the complete range of the company's products for test and measurement, SATCOM, telecom, commercial and military applications. Included in the Short Form Catalog are programmable attenuators, variable-step attenuators, continuously variable attenuators, toggle switch attenuators, fixed attenuators, terminations, loads, DC blocks, bias tees, impedance matching pads, RF fuses, RF switches, resistive dividers, return loss bridges and RF detectors.

Alan Industries
Columbus, IN (812) 372-8869, www.alanindustries.com

RS No. 320



High-Frequency Products Catalog

Providing a wide range of devices, IRC's Advanced Film Division has released a high-frequency products catalog for RF and microwave design engineers. IRC's family of line terminators and attenuators include both chip and flanged high power RF and microwave devices. The terminators and attenuators specified in the catalog combine high power dissipation with excellent high frequency performance.

IRC Advanced Film Division
Corpus Christi, TX (361) 992-7900, www.irctt.com

RS No. 321

High-power L-band Radar Amplifier

The Aethercomm Model SSPA 1.2-1.4-200 is a high power, pulsed RF amplifier that is employed in military

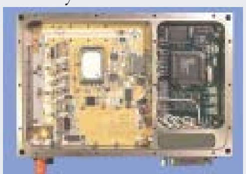
L-band radar systems and operates from 1200 to 1400 MHz. This PA was designed for L-band radars on fighter aircraft but can be employed in any system. The nominal peak input power is 0 dBm for the 200 W minimum peak output power. The amplifier employs a pulse width and duty cycle limiter to ensure no damage if the input is CW. RF rise and fall times are typically 40 ns. Harmonics are –50 dBc typical and in band spurs are < –70 dBc. Nominal pulse conditions are 10–100 µs but longer pulses can be utilized. The power flatness across the band is ±0.6 dB. Input and output VSWR is 1.5:1, typically.

Aethercomm Inc.,
San Marcos, CA (760) 598-4340,
www.aethercomm.com.

RS No. 216

X-band Synthesizer

Rodelco Electronics has designed a custom X-band synthesizer for airborne military radar



applications. The unit incorporates a C-band VCO, frequency divider and PLL circuitry to generate a synthesized C-band frequency that is then doubled to X-band. The microprocessor-controlled synthesizer delivers low phase noise and good spurious suppression while providing a leveled output power of +20 dBm over a 15 percent bandwidth at X-band.

Rodelco Electronics Corp.,
Ronkonkoma, NY (631) 981-0900,
www.rodelcocorp.com.

RS No. 217

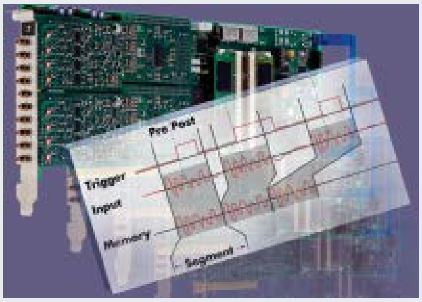
Double-ridged Guide Horn Antenna

A double-ridged guide horn antenna that offers a frequency range of 1 to 18 GHz is available from Schaffner EMC Inc. The versatile BHA 9118 is a linearly polarized, broadband antenna ideal for a wide range applications, particularly RF and EMC measurements to MIL, SAE, IEEE, IEC and FCC standards. The BHA 9118 can be used for both receiving (emissions) and transmitting (immunity) in chambers or open area test sites (OATS). It incorporates a precision "N" connector that provides good power handling capability and low voltage standing wave ratio (VSWR). The antenna has a field strength capability of 250 V/m at 1 m, and a high typical gain of 5.5–15 dBi.

Schaffner EMC Inc.,
Edison, NJ (732) 225-9533,
www.schaffnerusa.com.

RS No. 218

Radar-optimized Oscilloscope Cards

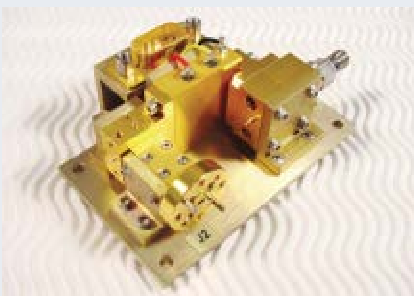


Strategic Test has introduced a Multiple Recording (MR) option for its UF2 family of 66 MHz PCI-based oscilloscope/digitizer cards. Primarily intended for recording radar signals, the MR option can be used to record any high-speed series of waveforms such as sonar, ultrasound and laser. The MR option allows an engineer to acquire a fast series of waveforms with a high repetition rate without restarting the hardware during the short dead time (usually only a few milliseconds) between waveforms. Each channel has its own trigger detection with level, edge, re-arm, window and steepness trigger.

Strategic Test Corp.,
Woburn, MA (617) 621-0080,
www.strategic-test.com.

RS No. 219

Space-based W-band Multiplier



Spacek Labs' Model A3X2X91F W-band multiplier assembly is available space qualified and is made entirely of Spacek Labs components. The A3X2X91F consists of a X2 frequency multiplier feeding a power amplifier followed by a X3 frequency multiplier. A combination high-pass/low-pass waveguide filter provides suppression of unwanted harmonics for this W-band multiplier. This LO source multiplier drove the Spacek Labs manufactured mixers for the transmitter and receiver front-end of the CloudSat Program Cloud Profiling Radar.

Spacek Labs,
Santa Barbara, CA (805) 564-4404,
www.spaceklabs.com.

RS No. 220

L-band LNA

Advanced Microwave has introduced its WLA2052 low-cost, L-band LNA. The WLA2052 exhibits extremely low noise figure of 1.0 dB typical, 1.3 dB max from 0.4 to 2.0 GHz. The IP3 is +40 dBm at 1.0 GHz; +36 dBm min. The LNA also offers an internal regulator and DC reverse voltage protection. DC supply is provided through the output SMA connector or an external pin as an option. Due to the extremely low-noise and high IP3, this LNA is ideally suited as an antenna mount front-end amplifier and can accept high levels of multiple signals with minimal distortion or minimal intermodulation product.

Advanced Microwave Inc.,
Sunnyvale, CA (408) 739-4214,
www.advmic.com.

RS No. 221

SRD Ceramic Chip Antenna

The 0868AT43A0020 antenna from Johanson Technology Inc. (JTI) was designed for the popular European 868 MHz Short Range Device (SRD) band, ETSI EN 300 220. This ceramic chip antenna provides a cost-effective solution for space-constrained applications, such as RFID and Zigbee. The antenna is very compact (7 × 2 × 0.8 mm) and offers excellent performance with an average gain of –4.0 dBi (XZ-total), with PCB assemblies as small as 50 × 20 mm.

Johanson Technology,
Camarillo, CA (805) 389-1166,
www.johansontechnology.com.

RS No. 222

Millimeter-wave Directional Couplers

Narda Microwave, an L-3 Communications company, has introduced a family of directional

couplers for frequency ranges from 1 to 40 GHz. They are intended for electronic warfare, radar, communications and test equipment applications. The Model 4018-20 covers 18 to 40 GHz with coupling of 20 dB ±1.25 dB, frequency sensitivity of ±0.8 dB and insertion loss of 1.45 dB, and can handle input powers of 30 W average and 3 kW peak. The Model 4018-10 also covers 18 to 40 GHz, with coupling of 10 dB ±1.25 dB, frequency sensitivity of ±0.8 dB, insertion loss of 2.0 dB, and a power handling ability of 30 W average and 3 kW peak. Both couplers have maximum input and output VSWR of 1.9:1, directivity of 12 dB, and weigh only 1 oz. The Model 4229-10 covers 1 to 40 GHz with coupling of 10 dB ±1.5 dB, frequency sensitivity of ±1.0 dB, insertion loss of 2.4 dB, and power handling ability of 20 W average and 3 kW peak. Directivity is at least 12 dB and maximum input and output VSWR is 1.75 dB.

Narda Microwave,
Hauppauge, NY (631) 231-1700,
www.nardamicrowave.com.

RS No. 223

COMPONENTS

MMIC Receiver and Transmitter Chipset

Mimix Broadband Inc. introduced surface mount technology (SMT) packaged gallium arsenide (GaAs) monolithic microwave integrated circuit (MMIC) receiver and transmitter devices that cover the 10 to 18 GHz frequency bands. The receiver has a noise figure of 2.7 dB and 20 dB image rejection across the band. The transmitter has a +11 dBm output P1dB, 8 dB conversion gain and 15 dB image rejection across the band. The receiver integrates an image reject mixer, an LO buffer amplifier and a low noise amplifier. The transmitter integrates a balanced, image-reject mixer, an LO buffer amplifier and an output RF amplifier. This receiver and transmitter pair, identified as XR1007-QD and XU1005-QD respectively, is well suited for wireless communications applications such as millimeter-wave point-to-point radio, local multipoint distribution services (LMDS), SATCOM and VSAT applications.

Mimix Broadband Inc.,
Houston, TX (281) 988-4600,
www.mimixbroadband.com.

RS No. 224

High Reliability Mixer

Mini-Circuits introduces the ADE-R10+ high reliability mixer. It features a proven diode quad in a hermitically sealed package and operates over a wideband of 10 to 1000 MHz with an LO power of 7 dBm. It has a high L-R isolation of 44 to 70 dB typical over the entire band which results in excellent carrier rejection in applications such as I&Q demodulators, and reduces filtering requirement in receivers/transmitters. It has a wide IF bandwidth of DC-800 MHz, making it suitable for applications such as phase detectors, up/down converters etc.

Mini-Circuits,
Brooklyn, NY (718) 934-4500,
www.minicircuits.com.

RS No. 225

EMI-filtered Audio Connectors

Spectrum Control Inc. has modified the standard MIL-DTL-55116 connectors that are used in 60-volt audio frequency circuits with 0.5 amps of current to provide effective EMI filtering. Spectrum's connectors are waterproof and polarized, five or six pin electrical plugs/receptacles and can be designed for special and selectively loaded EMI filtering. These custom filtered connectors are ideal for military and civilian communication applications where harsh conditions are present. Spectrum's custom EMI filtered audio connectors have a capacitance value range of 10 pF–1 mF and are available in C and Pi circuit configurations.

Spectrum Control Inc.,
Fairview, PA (814) 474-0325,
www.specemc.com.

RS No. 226

DC-to-50 GHz Coaxial Adapter

The Krytar Model 3031 (within Series) DC-to-50-GHz coaxial adapter has a voltage standing wave ratio (maximum) of 1.10 from DC to 27.0 GHz, 1.15 from 27.0 to 40 GHz and 1.20 from 40 to 50 GHz. Multiple connector configurations are available. Delivery time from stock is up to 30 days. Complete specifications, application ideas, technical notes and outline dimensions are available from the Krytar web site.

Krytar,
Sunnyvale, CA (408) 734-5999,
www.krytar.com.

RS No. 227

DC Blocking-impedance Matching Pads

BroadWave's Model 851879FMB is a 50 to 75 Ω impedance matching pad with a built-in DC block that eliminates impedance discontinuity (mismatches) and block DC current without introducing reflection to the circuit. This 1-watt device operates at 30 to 3000 MHz with SMA female/F male connectors. The VSWR is 1.30:1 and nominal insertion loss is 5.7 dB. Custom units are available in a variety of impedance and connector types operating up to 3 GHz. BroadWave Technologies impedance matching pads preserve signal integrity by matching virtually any transmission line.

BroadWave Technologies Inc.,
Franklin, IN (317) 346-6101,
www.broadwavetech.com.

RS No. 228

High-power Surface-mount Ceramic Filter

Lark has engineered a new High Power Surface Mount Ceramic Filter (SDP). This series is capable of handling up to 50 W and offers a frequency range of 1800 to 2200 MHz with a passband of 60 MHz, 0.35 dB insertion loss (maximum), 17 dBc return loss (minimum) and 0.2dB (maximum) Pk-to-Pk ripple in the passband. Rejection F_c ±430 MHz is 20 dBc (minimum) in a 0.75 × 1.09 × 0.62 in. package.

Lark Engineering Co.,
San Juan Capistrano, CA (949) 240-1233,
www.larkengineering.com.

RS No. 229

High-power Splitter/Combiner

The Model PmT-PD00506 is a high-power 0.5 to 6 GHz power splitter that has a phase and amplitude tracking of 2° and 0.2 dB, respectively. It can handle 500W CW and measures 5.5 × 2 × 0.7 in. It exhibits low insertion loss and high isolation.

Princeton Microwave Technology Inc.,
Mercerville, NJ (609) 586-8140,
www.princetonmicrowave.com.

RS No. 230

High-power Surface-mount Isolators

Renaissance Electronics Corp. (REC) has introduced a new line of one-inch square, surface-mount coplanar circulators and isolators for high-power applications (SMC Series). These circulators are distinguished by superior high power performance in the congested multi-carrier environment. Models are available in typical bandwidths of 10 to 15 percent with isolation of > 22 dB and insertion loss of < 0.35 dB.

Renaissance Electronics Corp.,
Harvard, MA (978) 772-7774,
www.rec-usa.com.

RS No. 231

High-current High-side Gate Driver

Fairchild Semiconductor's FAN7371 high-voltage gate driver IC (HVIC) with 4A current driving capability provides wide high-side driver operation with negative V_S swings of up to –9.8 V (at V_{BS} = 15 V), robust positive and negative V_B and an innovative common-mode dv/dt noise canceling circuit. Designed for driving MOSFETs and IGBTs in a wide array of applications up to 600 V including plasma display panel (PDP), high intensity discharge (HID) lighting, induction heating and other general purpose inverter applications, the FAN7371 providing stable performance against fluctuating temperatures in harsh environments. It increases reliability by providing under-voltage lockout (UVLO) for V_{BS} and a built-in 25 V shunt regulator.

Fairchild Semiconductor,
Korea, Bucheon, Korea
+82-32-680-1961,
www.fairchildsemi.com.

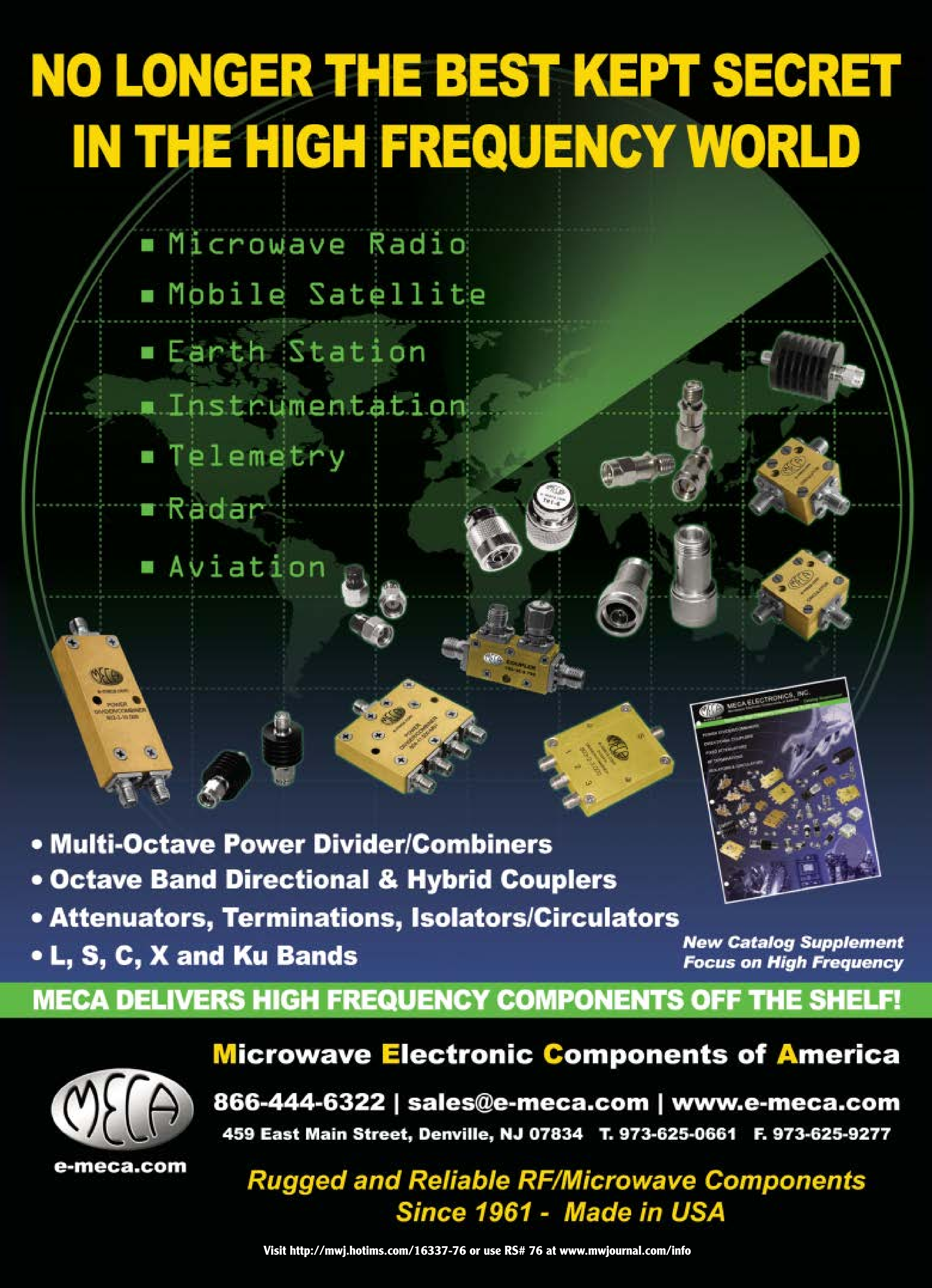
RS No. 232

GPS Dual Filter

Reactel part number 2DF-1227/1575-M is a moderately narrow-band dual filter that passes both the L1 and L2 GPS frequencies. It is the perfect unit for applications that are utilizing both of these GPS bands simultaneously, yet can only tolerate a two-port device. This small unit features loss of less than 3 dB and isolation in excess of 30 dB.

Reactel Inc.,
Gaithersburg, MD 301-519-3660,
www.reactel.com.

RS No. 242



NO LONGER THE BEST KEPT SECRET
IN THE HIGH FREQUENCY WORLD
■ Microwave Radio
■ Mobile Satellite
■ Earth Station
■ Instrumentation
■ Telemetry
■ Radar
■ Aviation
• Multi-Octave Power Divider/Combiners
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Elliptic Bandpass Filter

Lorch Microwave's 13BP5-137.5/X80-S is an elliptic bandpass filter with amplitude and phase equalizers to achieve 0.5 dB flat passband and ±5° phase linearity from 97.5 to 177.5 MHz. The filter features 3 dB nominal bw of 100 MHz. Rejection is 35 dB min at 77.5 MHz and 30 dB min at 195 MHz. The VSWR is 2.0:1 max across 97.5 to 177.5 MHz. The physical size is 4.5 × 1.25 × 1.0, excluding SMA-female connectors.
Lorch Microwave,
Salisbury, MD (410) 860-5100,
www.lorch.com.

RS No. 243

High-power UHF Notch Filter

K & L Microwave's WSN-00278 is a notch filter optimized for very steep skirts and for low-

loss. By exploiting mixed technologies, such as TEM resonators, suspended-substrate strip-lines and lumped components, the filter exhibits the best trade-offs of performance to volume ratio. There are several applications for this filter, ranging from rejecting signals at around 500 MHz from a nearby Tx antenna, to eliminating an unwanted harmonic from a transmitter, while the rest of the spectrum remains unaffected.
K & L Microwave,
Salisbury, MD (410) 749-2424,
www.klmicrowave.com.

RS No. 244

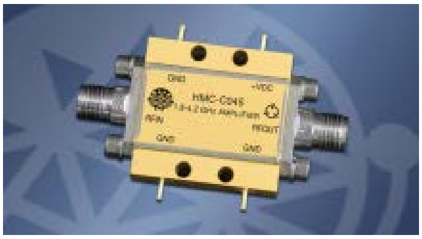
AMPLIFIERS

Solid-state Power Amplifier

The BC Systems Inc. Advanced RF Amplifier Model BCPA-225-450-100C is suitable for delivering reliable output power over the instantaneous frequency range of 225 to 450 MHz. The power amplifier (PA) is ideal for military communications, SATCOM, UHF LOS, DAMA and ECCM waveforms. The PA utilizes the latest in silicon LDMOS push-pull RF devices. The PA is fully self-protected from load VSWR, over temperature, out of band and input over drive.
BC Power Systems,
Setauket, NY (631)-751-9370,
www.bcpowersys.com.

RS No. 234

Connectorized Low-noise Amplifier Module



Hittite Microwave Corp. has introduced a new connectorized GaAs MMIC Low Noise Amplifier Module for a wide range of applications from 1.8 to 4.2 GHz. It combines the attributes of high gain, high output IP3 and high P1dB output power with a 0.7 dB noise figure. The HMC-C045 Low Noise Amplifier Module operates from 1.8 to 4.2 GHz, provides 26 dB of gain, and up to +26 dBm output IP3 and +15.5 dBm of output power at 1 dB compression, while operating from a single positive supply between +8 and +15 V.
Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343,
www.hittite.com.

RS No. 233

High-efficiency, Small-size 40/45 dB DLVA

American Microwave Corp. is offering the Model LVD-910-85 Option N-EGG high-efficiency, small-size 40/45 dB Detector Logarithmic Video Amplifier (DLVA) with picowatt sensitivity. It operates over the frequency range of 9.3 to 10.8 GHz. This DLVA has a logging range of –80 to –40/–35 dBm (TSS –85 dBm), minimum, with a linearity error of less than ±0.75 dB and a frequency flatness of ±1.0 dB. Rise and recovery times are 1.5 µs, maximum. Other octave band or 2 to 18 GHz units are available.

American Microwave Corp., Frederick, MD (301) 662-4700, www.americanmicrowavecorp.com.

RS No. 235

Solid-state Linear Amplifier

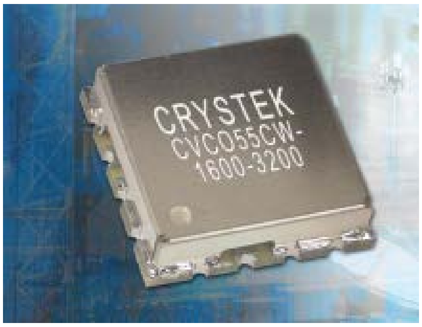
Comtech PST's Model BME158258-50 is a Class AB linear amplifier that operates over the full 1500 to 2500 MHz frequency range with output power of 50 W. The amplifier is very compact (6.4 × 2.5 × 1.5 in.) and weighs only 2 lb.

Comtech PST, Melville, NY (631) 777-8900, www.comtechpst.com.

RS No. 237

SOURCES

Wide-range VCO



Crystek's CVCO55CW-1600-3200 VCO operates from 1600 to 3200 MHz with a control voltage range of 0.5~20 V. This VCO fea-tures a typical phase noise of –93 dBc/Hz at 10 kHz offset and has excellent linearity. The model CVCO55CW-1600-3200 is packaged in the industry standard 0.5 × 0.5 in. SMD package. Input voltage is 5.0 V, with a max current consumption of 25 mA. Pulling and pushing are minimized to 8.00 MHz and 4.00 MHz/V, respectively. Second harmonic suppression is –15 dBc typical.

Crystek Corp., Ft. Myers, FL (239) 561-3311, www.crystek.com.

RS No. 238

PLL Frequency Synthesizer

EM Research's Thor Series frequency synthesizers are supplied as VCO-based fixed-frequency or serially programmable precision phase-locked frequency oscillators. Designed to cover a frequency range (in bands) from 50 MHz to 14 GHz and featuring very low power consumption, the THOR Series products are available with internal or external frequency references for stability, and exhibit exceptionally low phase noise characteristics.

EM Research Inc., Reno, NV (775) 345-2411, www.emresearch.com.

RS No. 239

Low-power OCXO

Valpey Fisher Corp. introduced the VFOV400 Series OCXO that offers extremely low power consumption (120 mW), 35 second warm up time, ±5 ppb stability and exceptional phase noise in a very compact package. The VFOV400 series OCXO offers a wide frequency range from 5 to 250 MHz. It is available with an HCMOS or SINEWAVE output and a supply voltage of either 3.3 or 5.0 V. Furthermore, the VFOV400 is designed with a robust four-point crystal mount to resist any sensitivity to vibration.

Valpey Fisher Corp., Hopkinton, MA (800) 982-5757, www.valpeyfisher.com.

RS No. 240

Low Phase Noise OCXO

MtronPTI introduced a 100 MHz OCXO featuring close-in phase noise performance. The XO5125 offers –130 dBc performance at 100 Hz offset as well as –70 and –100 dBc performance at 1 and 10 Hz offset, respectively. The phase noise performance along with the ±10 ppb stability performance over –40° to 80°C in a Euro Standard package supports many applications including automated test equipment (ATE), radar, communications and instrumentation. Other features of the XO5125 that meet a variety of market needs are the 2E-9 g-sensitivity, –168 dBc noise floor, 5E-7 aging and 7 dBm minimum sine wave output.

MtronPTI, Yankton, SD (605) 665-9321, www.mtronpti.com.

RS No. 241

SUBSYSTEM

High-dynamic Block Downconverter

MITEQ's Model LNB4044N01T is part of a line of low-noise (less than 3.3 dB), high-

dynamic block downconverters. The LNB4044N-01T incorporates a fixed frequency phase-locked LO to convert the 40 to 44 GHz RF to a 1 to 5 GHz IF band. These converters are packaged in a 5 × 5 in. ruggedized aluminum housing with flange mount and integrated waveguide input.

MITEQ Inc.,
Hauppauge, NY (631) 436-7400,
www.miteq.com.

RS No. 245

TEST EQUIPMENT

Extreme Temperature Probing Solution for Oscilloscopes

Agilent Technologies Inc. announced a probing solution for making oscilloscope measurements in environmental chambers and in other settings with extreme temperature conditions. The Agilent N5450A InfiniiMax extreme-temperature extension cable, used with the InfiniiMax Series probing system and Agilent Infiniium oscilloscopes, gives engineers the ability to probe signals at temperatures ranging from –55° to 150°C.

Agilent Technologies Inc.,
Santa Clara, CA (800) 829-4444,
www.agilent.com.

RS No. 247

Test Capability for RF Analyzers

Anritsu introduces the CDMA2000 1xEV-DO analysis capability for its MT8820B/ MT8815B Radio Communication Analyzers that allow for faster and more efficient testing of Rev. 0 and Rev. A terminals. The MT8820B-005/ MT8815B-005 1xEV-DO Measurement Hardware, MX882006C 1xEV-DO Measurement Software, MX882006C-002 1xEV-DO External Packet Data, and MX882006C-011 1xEV-DO Rev. A Measurement Software options enhance the testing capabilities of the MT8820B/MT8815B analyzers to provide manufacturers with a single-instrument test tool for conducting call-processing, RF Tx/Rx, and data transfer tests of 1xEV-DO terminals.

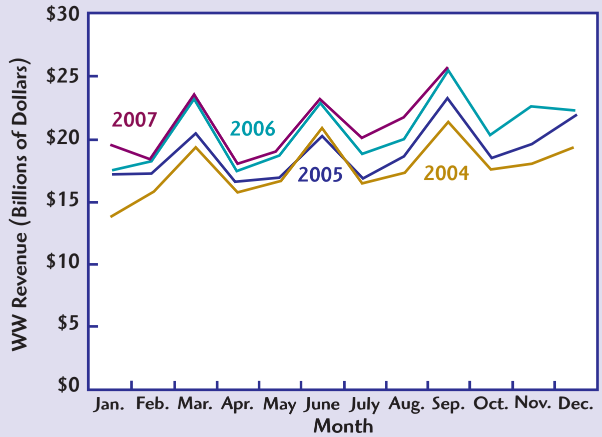
Anritsu Americas (Sales Office),
Richardson, TX (972) 761-4625,
www.anritsu.com.

RS No. 246

MONTHLY WORLDWIDE SEMICONDUCTOR REVENUE

The Semiconductor Industry Association (SIA) has released revenue numbers for September 2007 of $25.75 B (raw numbers not three-month moving average). The September numbers are up from $25.50 B in September of 2006 and represent 1.0% growth month-over-month versus 9.0% in August.

January 2007 started the year with strong growth but February showed negative growth. March moved positive again and April showed strengthening growth with May and June both showing negative growth. July and August showed strong positive growth before September's disappointing 1.0% growth.

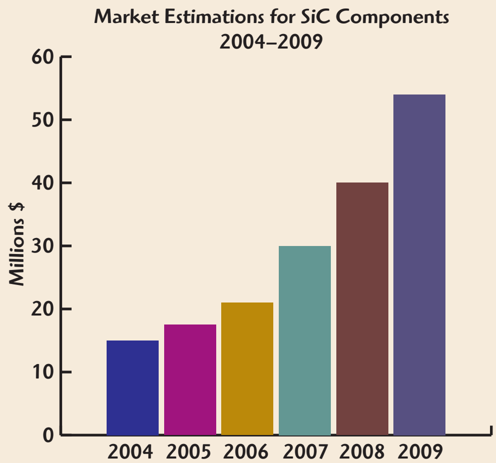


Source: IC Knowledge LLC, PO Box 20, Georgetown, MA 01833 (www.icknowledge.com)

SILICON CARBIDE ELECTRONICS MARKETS 2004–2009

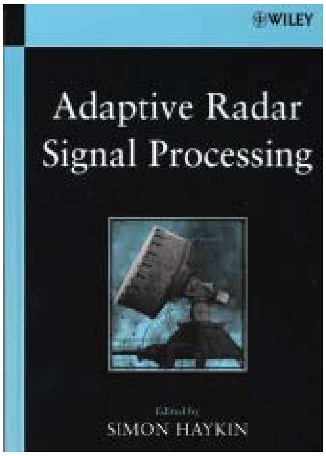
SiC devices display power densities and thermal properties well above those of either silicon or gallium arsenide. Such components are therefore ideal candidates for compact, highly efficient power circuits for use at high operating temperatures or in harsh radiation environments.

The first SiC devices to emerge consisted of Schottky diodes and MESFETs. Each has been commercially available for several years and the market has been growing quickly. Wicht Technologie Consulting (WTC) estimates that the market for these components could grow further, from about $13 M in 2004 to $53 M in 2009, equating to a compound annual growth of over 30%.



Source: Wicht Technologie Consulting, Frauenplatz 5, D-80331 Munich, Germany (www.wtc-consult.de)

Adaptive Radar Signal Processing



Simon Haykin, Editor
Wiley Interscience • 243 pages; $94.95
ISBN: 978-0-471-73582-3

This book focuses on two types of radar: Surveillance radar, the purpose of which is target detection in the presence of unwanted signals, interference and noise; and low tracking radar, which is complicated by multipath caused by reflections from the sea/ocean surface. The book is organized in two parts. Part I, consisting of two chapters, deals with radar spectrum analysis. Chapter 2 addresses the low-angle tracking radar problem. With estimation of the target's angle of arrival in the presence of the multipath issue of interference, a spectrum estimation procedure known as the multi-taper method or multiple-window method is used. Chapter 3 also uses the multi-taper method, but with an important extension. Specifically, the power spectrum is now estimated as a function of both time and frequency. Part II, consisting of Chapters 4 to 6, deals with dynamic models of radar returns produced in a marine environment. Chapter 4 focuses on modeling the underlying dynamics responsible for the generation of sea clutter. Three specific approaches are discussed: chaos, hybrid amplitude modulation-frequency modulation and the auto-regressive model. Chapter 5 expands on the ideas described on modulation theory in Chapter 4 and further refines this physical basis for the statistical characterization of sea clutter dynamics by accounting for nonstationarity. Chapter 6 completes the discussion on the dynamic of radar returns in a marine environment by formulating a Bayesian framework for detection-through-tracking of a target moving on the sea surface in the presence of sea clutter. As with Part I, the adaptive signal-processing theory presented in all three chapters of Part II is supported experimentally using real life radar data collected using the IPIX radar under different environmental conditions.

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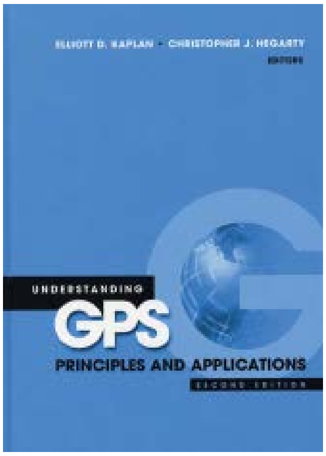
Understanding GPS Principles and Applications: Second Edition



Elliott D. Kaplan and Christopher J. Hegarty, Editors
Artech House • 720 pages; $129, £78
ISBN: 978-1-58053-894-7

Since the writing of the first edition of this book, usage of the Global Positioning System (GPS) has become nearly ubiquitous. The objective of this second edition is to provide the reader with a complete systems engineering treatment of GPS. Updates include the modification of some of the existing material and the addition of new material. The new material includes satellite constellation design guidelines, descriptions of new satellites (Block IIR, Block IIR-M, Block IIF), a comprehensive treatment of the control segment and planned upgrades, satellite signal modulation characteristics, descriptions of the modernized GPS satellite signals (L2C, L5 and M code) and advances in GPS receiver signal processing techniques. The treatment of interference effects on legacy GPS signals from the first edition is greatly expanded and a treatment of interference effects on modernized signals is added. New material is also included to provide in-depth discussion on multipath and ionospheric scintillation, along with the associated effects on the GPS signals. In addition to GPS, Galileo is now covered with as much detail as possible at this stage in this European program's development. Coverage of Russia's Global Navigation Satellite System (GLONASS), China's BeiDou and Japan's Quasi-Zenith Satellite System is also provided. As in the first edition, the book is structured such that a reader with a general science background can learn the basics of GPS and how it works within the first few chapters, whereas the reader with a stronger engineering/scientific background will be able to delve deeper and benefit from the more in-depth technical material.

To order this book, contact:
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SPST								
0.2 – 2	SW1-002020RN1NF	1.7	70	1.6:1	10/10	20	35	35/70
2 – 8	SW1-020080RN1NF	2	80	1.7:1	10/10	20	35	35/70
4 – 12	SW1-040120RN1NF	2.2	80	1.7:1	10/10	20	35	35/70
2 – 18	SW1-020180RN1NF	3	80	2:1	10/10	20	35	35/70
1 – 18	SW1-010180RN1NF	3	70	2:1	10/10	20	35	35/70
SP2T								
0.2 – 2	SW2-002020RN1NF	1.5	70	1.6:1	10/10	20	35	60/60
2 – 8	SW2-020080RN1NF	1.8	80	1.7:1	10/10	20	35	60/60
4 – 12	SW2-040120RN1NF	2.2	80	1.7:1	10/10	20	35	60/60
2 – 18	SW2-020180RN1NF	2.8	80	2:1	10/10	20	35	60/60
1 – 18	SW2-010180RN1NF	3	70	2:1	10/10	20	35	60/60
SP3T								
0.2 – 2	SW3-002020RN1NF	1.6	70	1.6:1	20/20	150	180	85/85
2 – 8	SW3-020080RN1NF	1.9	80	1.7:1	20/20	150	180	85/85
4 – 12	SW3-040120RN1NF	2.4	90	1.7:1	20/20	150	180	85/85
2 – 18	SW3-020180RN1NF	3	80	2:1	20/20	150	180	85/85
1 – 18	SW3-010180RN1NF	3.1	70	2:1	20/20	150	180	85/85

Note: The above models are all reflective switches. Absorptive models are also available, please contact MITEQ.

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S3W2	S3W5	N3W5	3	±0.40
S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	-0.4, +0.9
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	-0.4, +0.8
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60
S20W2	S20W5	N20W5	20	-0.5, +0.8
S30W2	S30W5	N30W5	30	±0.85
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*At 25°C includes frequency and power variations.

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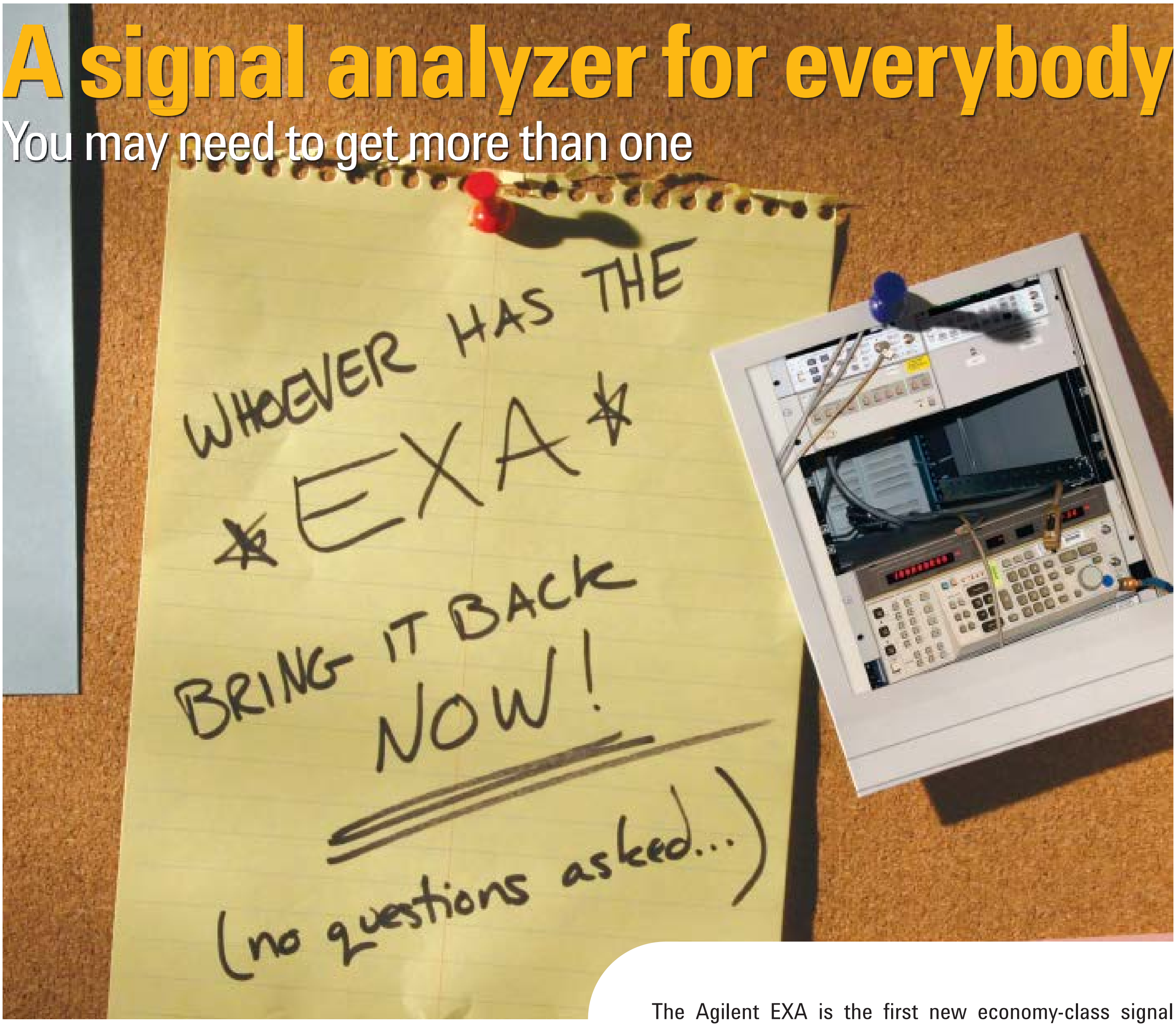

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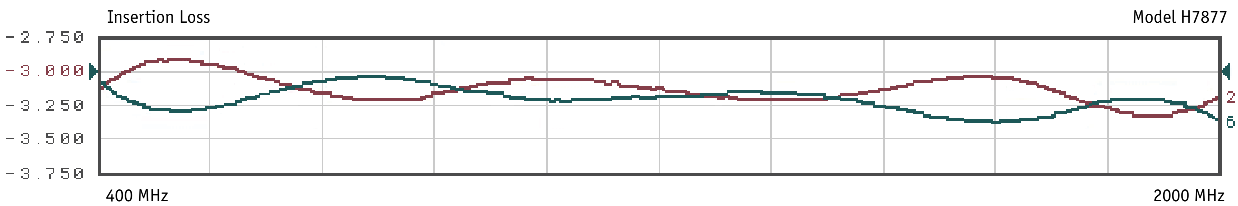

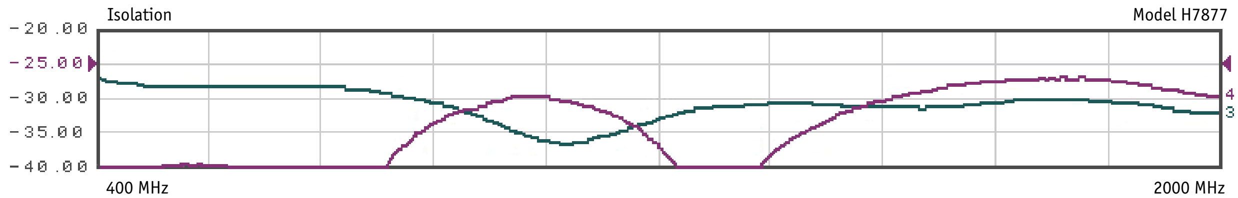

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Model	Frequency (MHz)	Power (Watts)	Insertion Loss (dB)	VSWR	Isolation (dB)	Size (Inches)
H6287	0.1-50	500	0.5	1.30:1	30	9 x 8 x 3.6
H6152	0.2-35	50	0.4	1.30:1	20	2.5 X 1.5 X 1.12
H1484	2-32	500	0.2	1.30:1	25	5 X 3 X 2
H6751	20-512	50	0.8	1.40:1	25	4 X 1.6 X 0.8
H7450	100-500	200	1.0	1.35:1	20	6 X 5 X 2.25
H7733*	100-500	2000	0.2	1.30:1	20	15 X 10 X 2
H3670	200-400	400	0.2	1.40:1	20	5 X 3 X 2.25
H7498*	200-1000	750	0.3	1.30:1	20	8.5 X 5 X 1.5
H7877*	400-2000	300	0.35	1.25:1	20	4.5 X 2.5 X 1.2
H7492*	500-2500	200	0.4	1.30:1	20	4 X 2.2 X 0.85

*Utilizing Werlatone's Patented Stripline Design to achieve extremely low loss and high isolation!