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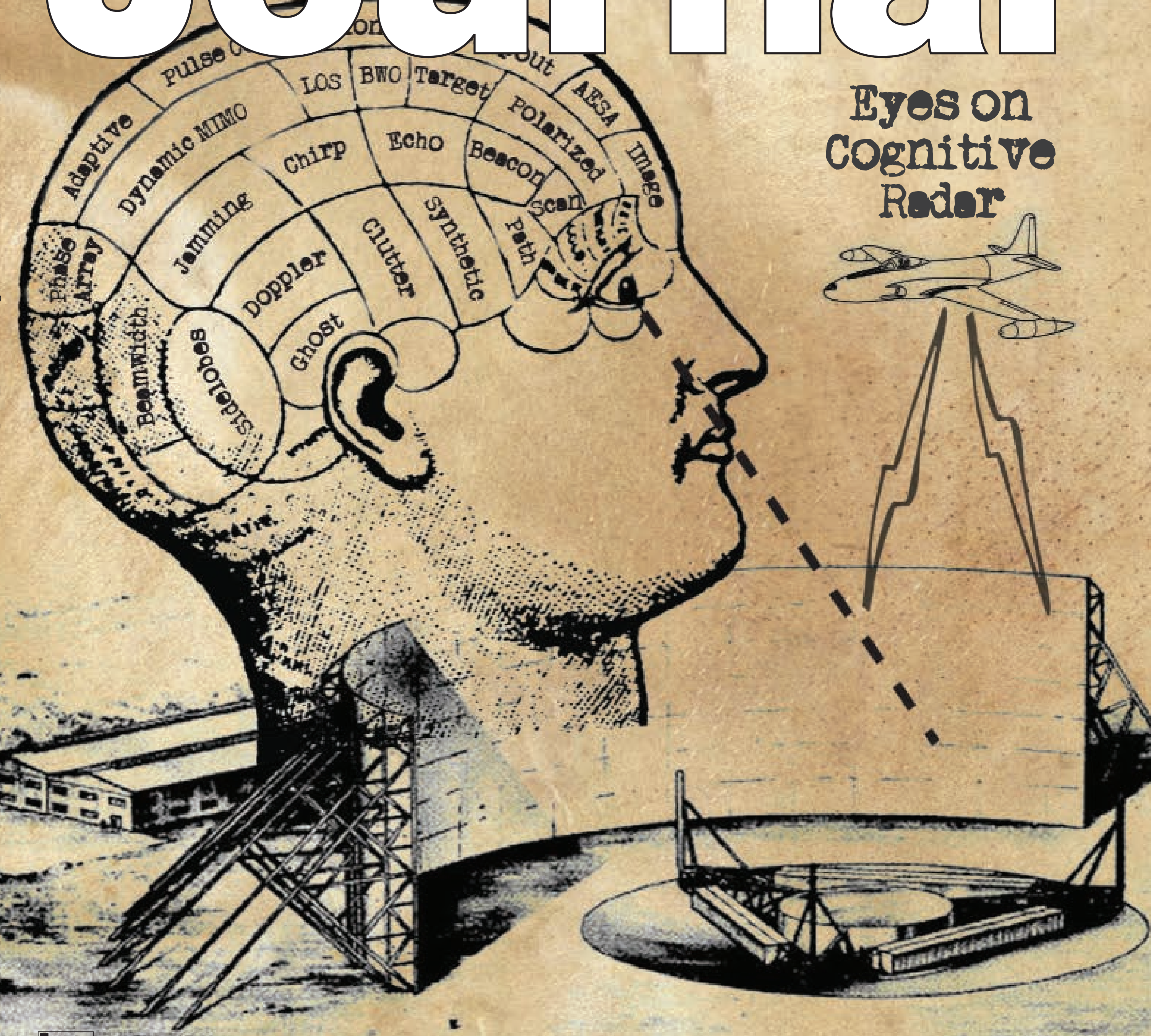
Microwave Journal

Eyes on Cognitive Radar



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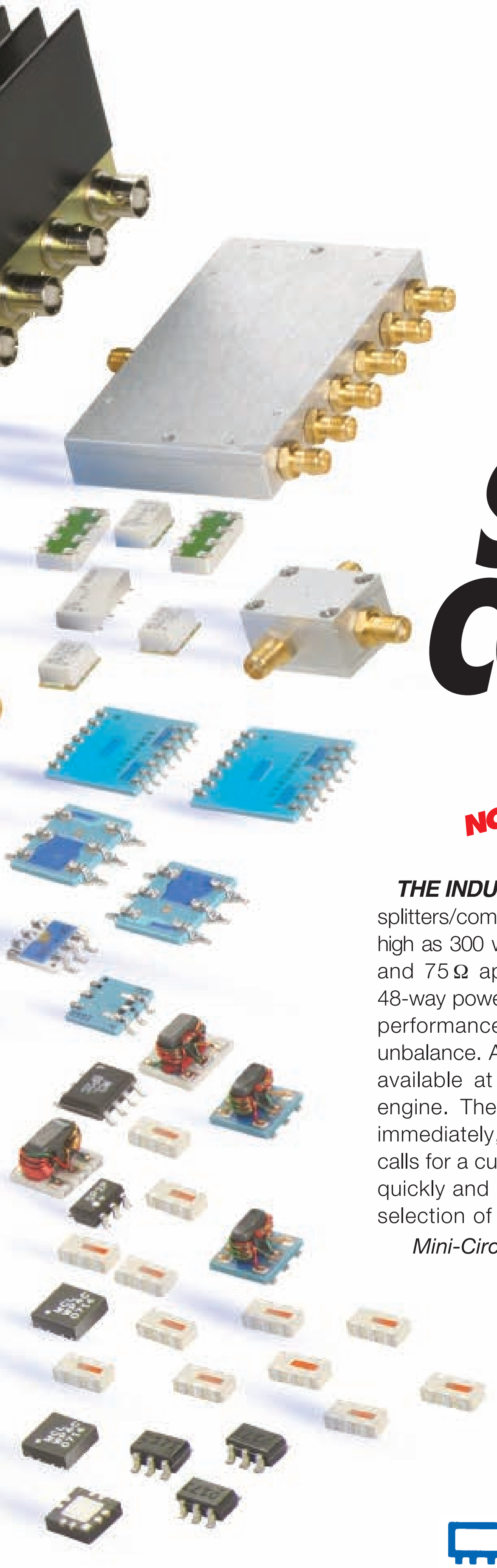

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Jwo-Shiun Sun, Ren-Hao Chen, Shao-kai Liu and Cheng-Fu Yang

Comparing Harmonic Load Pull Techniques with Regards to Power-Added Efficiency (PAE)
Application Note, Focus Microwave

FREQUENCY MATTERS

CARL SHEFFRES, *MICROWAVE JOURNAL* PUBLISHER

I recently returned from the APMC event in Yokohama, Japan. Now I don't mind travelling and I'm certainly used to the travails of business travel after all these years, but this was a particularly brutal journey. It basically took two days to get there with the flight and time difference and a full 24 hours to return. All this for three sleep deprived days at the conference and exhibition. The long flight home provided ample time to ponder the cost/benefit ratio of making the trip.

Now don't get me wrong. I'm a huge proponent of live events. There's nothing to compare with the opportunity to meet with people face-to-face and no better way to get briefed on new products and technology and to gauge the state of the industry. I met with numerous old friends and colleagues and met many new people and companies. It's also a great opportunity to experience new places and cultures. I have found Japan in particular to be intriguing and its people to be friendly, courteous and extremely hospitable. I enjoyed some good sushi too.

But what of all the folks who couldn't make the journey? There were very few Americans and Europeans represented, and they missed out on an excellent technical conference and a well-represented exhibition.

This is why I'm also a huge proponent of virtual events. More and more live conferences are adding a virtual component to their events. There are a variety of models offered, but they're all pretty sleek and they allow those who are unable to be physically present to reap the educational and some of the interactive benefits that these conferences and exhibitions provide. And all this from the comfort of your office or home and without any airport security pat-downs.

Last fall during the European Microwave Week event, *Microwave Journal* partnered with the European Microwave Association (Eu*M*A) to produce the "Defence/Security Executive Forum," which drew a crowd of nearly 200. The event was video taped and portions can be viewed on mwjournal.com; the presentations can be downloaded as well. Many of our readers have done so. Look for a far greater virtual presence at EuMW 2011.

At CTIA Wireless 2011 this coming March, MWJ has organized the 3rd annual RF/Microwave Zone Pavilion. In conjunction, we will be hosting a seminar for the first time, titled "Understanding MIMO OTA Testing: A Simple Solution to a Complex Test." The leading experts on MIMO will be presenting live and the forum will be recorded for on-demand webinar viewing, allowing those not present at CTIA to view what promises to be an informative presentation on cutting-edge technology.

Webinars are clearly the hottest virtual environment at the present time. For MWJ, 2010 was a turning point, with nearly twice as many webinars produced than the prior year. We're fortunate to work with prestigious partners such as Besser Associates and Strategy Analytics, but we've also seen a big increase in vendor webinars. More than 7,000 of you have attended one of these webinars live and many more have accessed them on-demand. If you have not had the chance to attend one of these events, I highly recommend it. I think you'll find that they are well worth your time.

I'll be travelling to nearly a dozen conferences this year, and I look forward to each one. They are my opportunity to stay current, stay networked and meet new people. I'll also be attending numerous events from my laptop and looking for new ways to bring information directly to you. I hope to see you online, in-person or both.

Happy New Year,
Carl Sheffres

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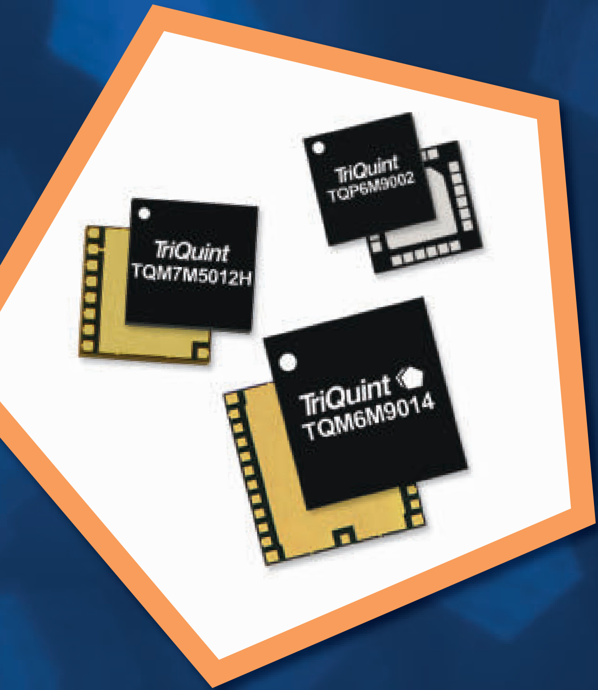

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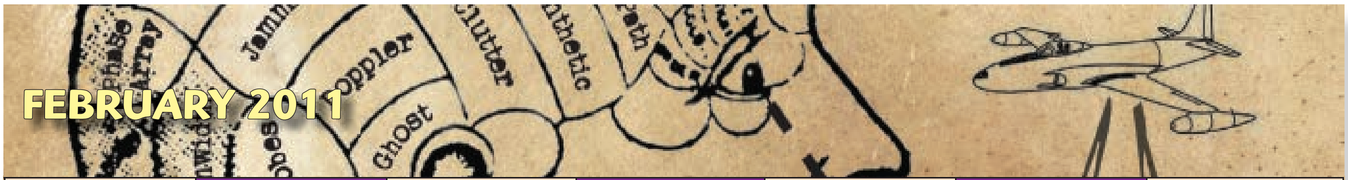

FEBRUARY 2011

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
30	31	1 DesignCon 2011, Santa Clara, CA	2	3	4	5
6	7	8	9	10	11	12
13	14	15 Mobile World Congress, Barcelona | 14-17 February 2011, Barcelona, Spain; **MWJ/Besser Webinar: PA Linearization Techniques**	16	17 **CST STUDIO SUITE Microwave and Antenna Training** Rome, Italy	18	19
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27	28	1	2	3	4	5

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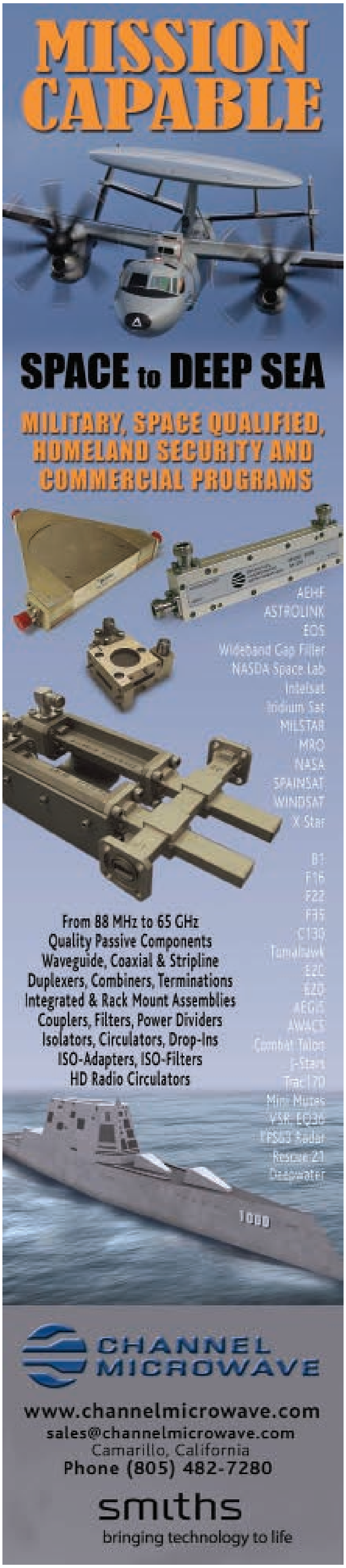

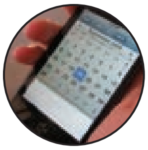

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JANUARY

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IEEE International Conference on Micro Electromechanical Systems
January 23–27, 2011 • Cancun, Mexico
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DesignCon 2011
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www.designcon.com

FEBRUARY

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Mobile World Congress
February 14–17, 2011 • Barcelona, Spain
www.mobileworldcongress.com

ISSCC 2011
International Solid-State Circuits Conference
February 20–24, 2011 • San Francisco, CA
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Nate 2011
National Association of Tower Erectors
February 21–24, 2011 • Oklahoma City, OK
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SATELLITE 2011
March 14–17, 2011 • Washington, DC
www.satellite2011.com

CTIA with RF/Microwave and M2M Zones
March 22–24, 2011 • Orlando, FL
www.ctiawireless.com

ACES 2011
27th International Review of Progress in Applied Computational Electromagnetics
March 27–31, 2011 • Williamsburg, VA
http://aces.ee.olemiss.edu/conference/

APRIL

ARMMS RF and Microwave Society Conference
April 4–5, 2011 • Oxfordshire, UK
www.armms.org

WAMICON 2011
IEEE Wireless and Microwave Technology Conference
April 18–19, 2011 • Clearwater, FL
www.wamicon.org

JUNE

MIE 2011
2011 National Conference on Microwave and Millimeter Wave in China
2011 Microwave Industry Exhibition in China
June 4–7, 2011 • Qingdao, Shandong, China
www.cnmw.org

RFIC 2011
IEEE Radio Frequency Integrated Circuits Symposium
June 5–7, 2011 • Baltimore, MD
www.rfic2011.org

IMS 2011
IEEE MTT-S International Microwave Symposium
June 5–10, 2011 • Baltimore, MD
www.ims2011.org

ARFTG 2011
ARFTG Microwave Measurement Conference
June 10, 2011 • Baltimore, MD
www.arftg.org

AUGUST

EMC 2011
IEEE International Symposium on Electromagnetic Compatibility
August 14–19, 2011 • Long Beach, CA
www.emc2011.org

OCTOBER

EuMW 2011
European Microwave Week
October 9–14, 2011 • Manchester, UK
www.eumweek.com

AMTA 2011
33rd Annual Symposium of the Antenna Measurement Techniques Association
October 16–21, 2011 • Englewood, CO
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COVER FEATURE
INVITED PAPER

Cognitive Radar: The Next Radar Wave?

The continued "digitization" of radar front-ends and resultant transmit-receive flexibility, coupled with advances in advanced knowledge-aided (KA) high performance embedded computing (HPEC), have afforded a unique opportunity for a leap-ahead capability in a radar's ability to adapt to complex target-environment scenarios. This article provides an overview of one of the latest adaptive radar architectures to emerge from the nascent field of cognitive radar.

Fundamentally, cognitive radar refers to the next generation of adaptive radar that has unprecedented transmit-receive adaptivity and diversity, along with "intelligent" high performance embedded computing; in other words, the radar adapts "intelligently" to its environment based on a plurality of potential information sources.[1,2] Consider the definition of cognition afforded by the National Institute of Mental Health:[3] "Cognition: Conscious mental activity that informs a person about his or her environment. Cognitive actions include perceiving, thinking, reasoning, judging, problem solving and remembering."

A mapping of these attributes to a cognitive radar architecture is provided in ***Table 1***.

TABLE I
MAPPING OF BIOLOGICAL COGNITIVE PROPERTIES TO THAT OF A COGNITIVE RADAR

Cognitive Property	*Cognitive Radar Equivalent*
Perceiving	Sensing
Thinking, Reasoning, Judging, Problem Solving	Expert Systems, Rule-based Reasoning, Adaptive Alogrithms and Computation
Remembering	Memory, Environmental Database

(Note: Do not worry if some of these terms are unfamiliar at the moment—read on!) While some of these attributes are present to some degree in conventional radars—adaptive receiver processing, for example (that is adaptive beamforming, adaptive constant false alarm rate (CFAR), thresholding, etc.)[4]—they are generally highly constrained and specialized due to the demands of real-time signal throughput and available real-time knowledge sources. Cognitive radar architectures offer the potential of dramatically improving the sophistication of adaptivity (both transmit and receive), through the exploitation of a plurality of knowledge sources (both endogenous (internal) and/or exogenous (external)).[2]

What is driving the need for cognitive radar? ***Table 2*** highlights just some of the challenges facing modern radars that, in principle, can be alleviated by incorporating cognitive radar concepts: Everything from complex, highly chaotic clutter (both natural and manmade), to advanced electronic attack and spectrum crowding.[5] Conventional adaptive radars rely

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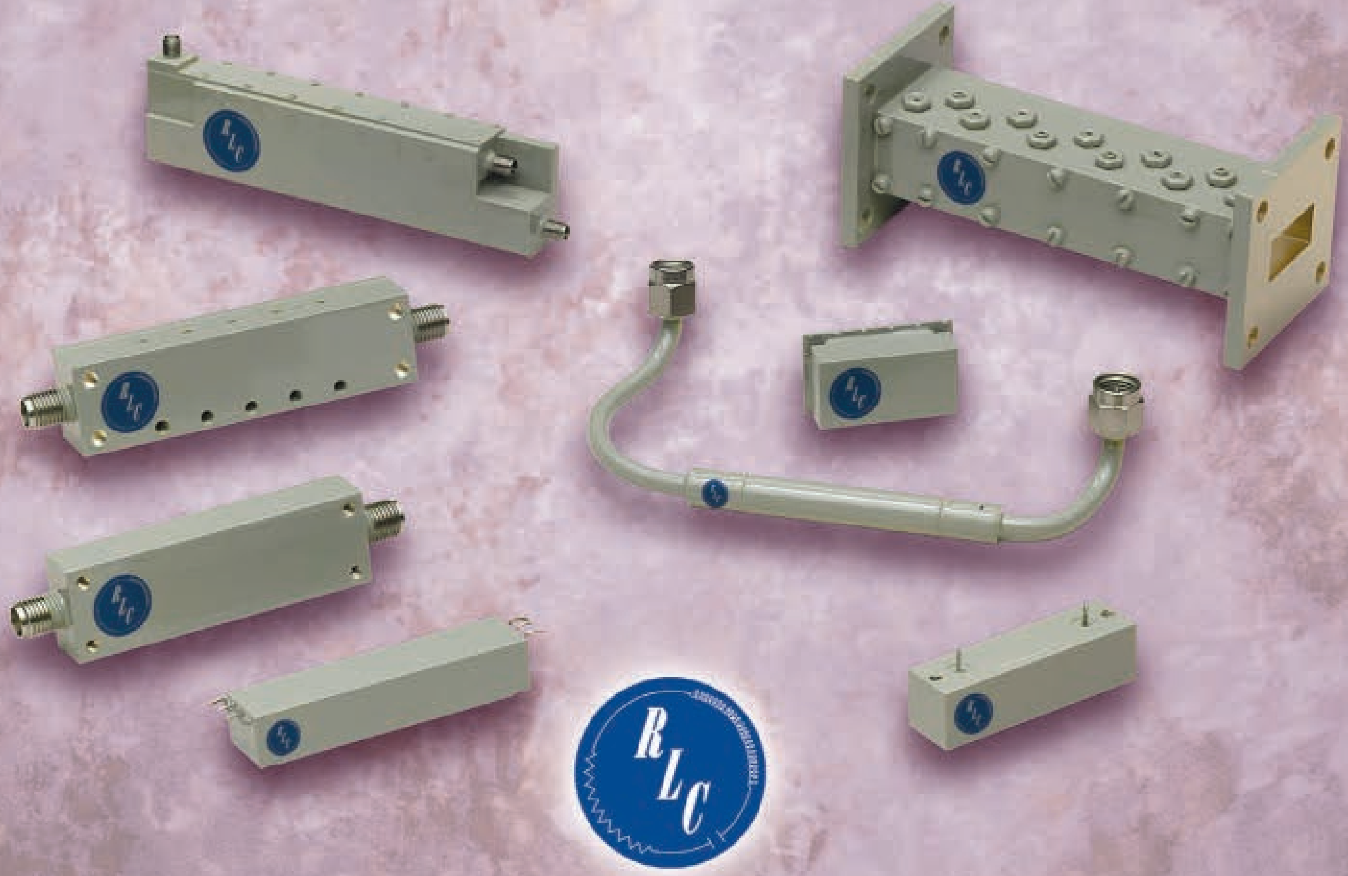

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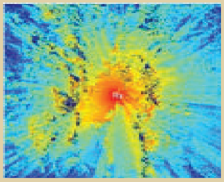
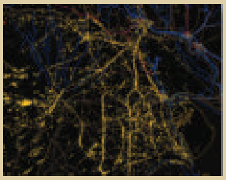
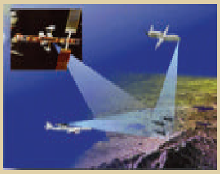
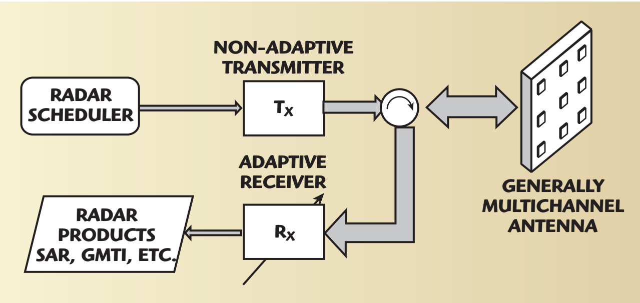
TABLE II
EXAMPLES OF REAL-WORLD PHENOMENON AND THEIR DELETERIOUS IMPACTS ON PERFORMANCE

Phenomenon	Illustration	Impact
Heterogeneous clutter		Over/under-nulled clutter, increased false-alarms, desensitization, lack of training data
Dense target backgrounds		Desensitization, lack of training data, increased false alarms
Large discretes, large manmade structures	 	Increased false alarms, target masking
Configuration-induced non-stationary clutter behavior (e.g., bistatic radar, nonlinear arrays, etc.)		Lack of training data
Electronic countermeasures		Varying impact
Crowded spectrum		Varying impact to radar and external users



▲ *Fig. 1 Example of a conventional (non-cognitive) radar.*[5]

exclusively on sample statistics derived from the received data stream and, consequently, can suffer a loss in performance in highly non-stationary interference environments.[6] Cognitive radars aim to provide much more sophisticated methods of adaptation using high fidelity contextual (such as environmental) knowledge sources, as well as organic sensor data.[2]

Before delving into the details of a cognitive radar, let us first consider how a modern conventional radar operates. While fairly generic, we will focus on architectures associated with modern airborne moving target indicator (MTI) (either air-to-air (AMTI) or air-to-ground (GMTI)),[4] which often have the most demanding requirements due to complex (and potentially hostile) operating environments.[7]

Referring to ***Figure 1***, there are four high level salient functional elements of the generic MTI radar architecture:

- Radar Scheduler
- Transmit Chain
- Receive Chain
- Data Product Generation

Note that virtually all true "channel adaptivity" (adaptivity to the ever changing target plus interference environment) occurs only in the receive chain—and a highly constrained adaptivity at that, as previously described. Conventional radar transmit chains generally employ non-adaptive (and often "pre-canned") waveforms, which at best employ only mode flexibility (PRF, bandwidth, etc.). By far the most ubiquitous waveforms are the family of linear frequency modulation (LFM), which enjoy a number of properties amenable to cost-effective hardware implementation and robust and reliable implementation (a discussion on "stretch" and other LFM properties, such as Doppler mismatch tolerance has been described by Richards).[4] Note that this lack of transmit waveform diversity essentially precludes "feedback" from the receive chain to the transmitter. As has been emphasized by Haykin,[1] this feedback is an essential element of any cognitive sensor system. Thus, at best, adaptivity of the radar scheduler is reduced to adaptive "mode" selection (that is high versus low PRF, etc.).

Now contrast the conventional radar architecture with that of a cognitive radar, an example of which is depicted in ***Figure 2***. Note the addition of a number of additional subsystems and additional adaptivity:

- Adaptive Radar Scheduler
- Adaptive Transmit Chain
- Adaptive Receive Chain
- Environmental Dynamic Database (EDDB)
- Knowledge-Aided (KA) Coprocessor
- Data Product Generation

The inclusion of a knowledge-aided (KA) coprocessor and environmental dynamic database (EDDB) allow for the inclusion of new information sources to aid in overall adaptivity. Note the inclusion of feedback to the transmitter, which has been identified by Haykin as an essential element of any cognitive sensor system.[1]

The two main new elements are adaptivity on transmit and the introduction of knowledge-aided (KA) processing. Both of these subsystems are discussed in greater detail later in this

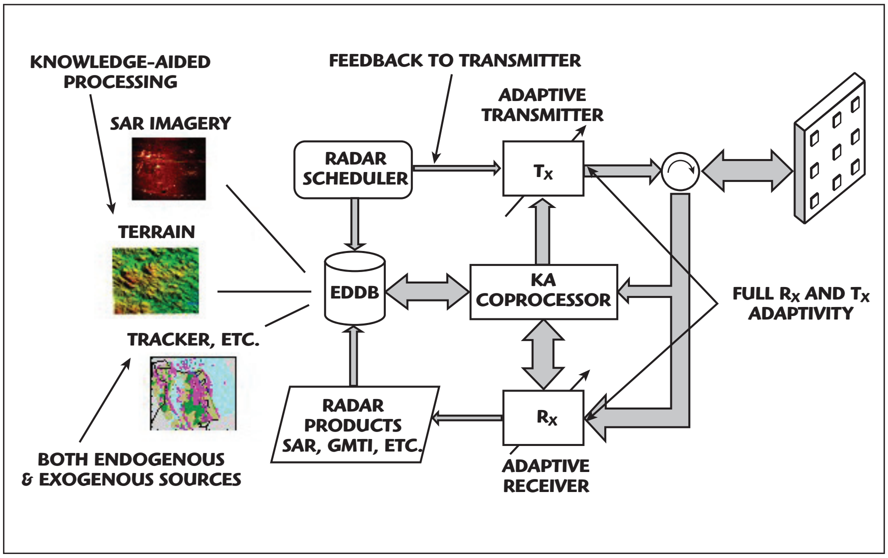


Fig. 2 Example of a knowledge-aided (KA), fully adaptive cognitive radar architecture.[5]

article. The role of the KA coprocessor and the EDDB is fundamentally to provide an accurate estimate of the dynamic radar channel.

For example, in the case of complex clutter, not only is the receive radar data stream available for sensing the clutter environment, but a multitude of knowledge sources are now available in the EDDB and accessible in real-time through an HPEC architecture pioneered by the Defense Advanced Research Projects Agency's (DARPA) KASSPER project[5] (see section titled "Knowledge-Aided Processing for Enhanced Real-Time Adaptivity").

As the name implies, the new adaptive transmit chain allows for the channel adaptivity of all transmit degrees-of-freedom (DoF), including waveform, spatial (such as az-el transmit adaptivity), polarimetric, etc.[2] Note the inclusion of a specific feedback path from the receive and KA processing chains to the adaptive transmitter, a prerequisite for cognitive behavior as previously discussed. The following sections delve deeper into the adaptive transmit and KA processing chains.

ADAPTIVE TRANSMIT FUNCTIONALITY

As previously mentioned, conventional radars do not possess true channel adaptivity, but provide mode selectability (usually based on macroscopic criteria such as search, versus track, versus ID). There are many reasons why this is the case, from the lack of flexible front-end hardware (such as digital arbitrary waveform generators (DAWG)), to a lack of the basic theory of optimum channel transmit adaptivity. However, continued advances in the "digitization" of radar front-ends, including DAWGs and advanced HPEC, have all but removed the first excuse—the hardware either now exists or soon will. The remaining question is more one of developing the theory and application of adaptive transmit functionality.

Consider ***Figure 3***, which depicts the basic multi-input, multi-output (MIMO) signal flow block diagram of a radar interacting with a target in the presence of generally additive colored noise. The discrete, matrix algebraic formulation is completely general and can accommodate a multitude of radar degrees-of-freedoms (DoF), such as fast (waveform) and slow-time (Doppler), as well as special and polarimetric DoFs. Note the use of a matrix algebraic formulation, which greatly simplifies notation is justified due to the finite bandwidth nature of all constituent signals and systems.[8] For example, the N-dimensional input vector s might be comprised of the samples (fast-time) of the transmit waveform, that is

$$s = \begin{bmatrix} s(0) \\ s(\tau) \\ \vdots \\ s((N-1)\tau) \end{bmatrix} \qquad (1)$$

Or, for the multi-input case, it might consist of the waveforms being trans-

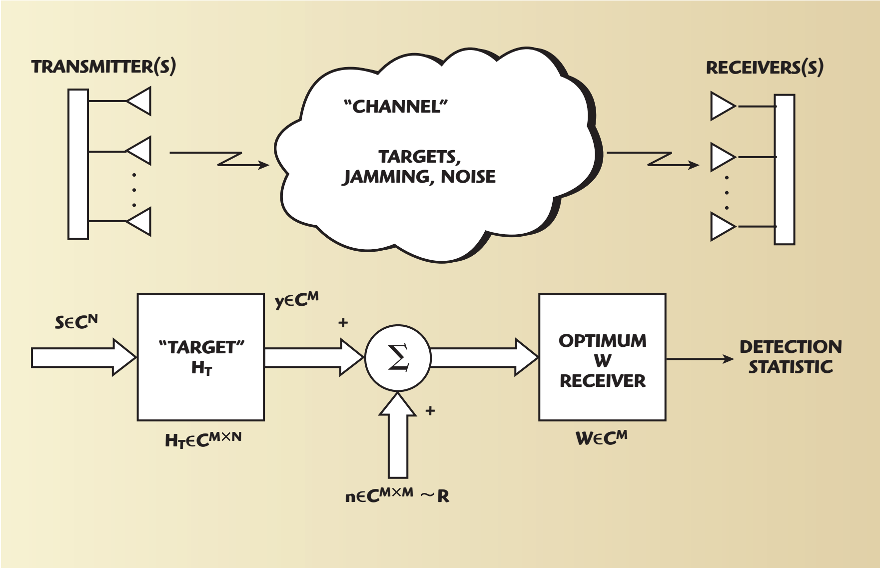


Fig. 3 Basic signal flow block diagram for a multi-input, multi-output (MIMO) radar.[5]

mitted from each transmit subarray, that is

$$s = \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_N \end{bmatrix} \quad (2)$$

where s_i denotes the vector of waveform samples from the i-th transmit subarray. The N × M target transfer function H_T is similarly defined. For example, assuming a causal, linear time invariant (LTI) impulse response for the target, the elements of H_T would have the form

$$H_T = \begin{bmatrix} h[0] & 0 & \cdots & 0 \\ h[\tau] & h[0] & & \vdots \\ \vdots & & \ddots & 0 \\ h[(N-1)\tau] & \cdots & h[\tau] & h[0] \end{bmatrix} \quad (3)$$

where h[nt] denotes the n-th sample of the target (fast-time) impulse response.

Assume one wants to maximize the probability of detecting the target by a joint optimization of both the transmit and receive functions. For the Gaussian case, this is tantamount to maximizing the output signal-to-interference-plus-noise-ratio (SINR).[9] Although the solution is relatively straightforward, the reader is referred to Reference 2 for exact details. We will simply highlight the method by which the solution is achieved, and state the result.

We begin at the receiver: The optimum receiver, for the additive (and independent) noise case, consists of a whitening filter H_w, followed by a white-noise matched filter, such as a matched filter "matched" to the whitened target echo.[2] Assuming that the colored noise (which generally consists of external colored noise sources and internal receiver (white) noise) has a positive definite covariance matrix R,[9] H_w is equal to the matrix square root of the inverse covariance matrix, that is

$$H_w = R^{-1/2} \quad (4)$$

Thus, the output of the whitening filter y is of the form

$$\begin{aligned} \mathbf{y} &= \mathbf{y}_s + \mathbf{n} \\ &= H_w H_T \mathbf{s} + \mathbf{n} \end{aligned} \quad (5)$$

where **n** is a vector (generally complex) zero mean, unity variance noise source (identity covariance matrix). All that remains is to optimize the input s. This is readily accomplished by recognizing that maximizing the output SINR is equivalent to maximizing the energy in the whitened target echo, that is

$$s_{opt} \rightarrow \max_{s} |y'y| \quad (6)$$

A straightforward application of Schwarz's inequality[10] yields the desired solution

$$(H'H)s_{opt} = \lambda_{max} s_{opt} \quad (7)$$

where H is the composite channel transfer function, consisting of the cascade of the target and whitening filter transfer functions, that is

$$H \triangleq H_w H_T \qquad (8)$$

In other words, the optimum input (transmit waveform, for example) is that eigenfunction (solution) of Equation 7, with maximum associated eigenvalue.[2] Interestingly, although relatively straightforward, the above result (and derivation) are not found in existing radar texts. This is because optimizing the transmitter in response to the composite channel is not done in practice.

Figure 4 shows an example of an additive colored noise source, resulting from a multipath broadband interferer.[5] ***Figure 5*** shows the resulting potential benefits of adapting the transmit waveform when a colored noise source is present, in this case in the form of a broadband interference source undergoing terrain scatter (multipath interference). The solution to Equation 7 yields a greater than 8 dB improvement in output SINR, compared to a non-adaptive conventional chirp (LFM) waveform.[2] While this example only considered fast-time DoFs (that is waveform), the formulation is completely general and can accommodate other DoFs such as spatial and polarimetric.

KNOWLEDGE-AIDED PROCESSING FOR ENHANCED REAL-TIME ADAPTIVITY

Beginning in 2001, the Defense Advanced Research Projects Agency (DARPA), in collaboration with the Air Force Research Laboratory (AFRL), initiated the Knowledge-Aided Sensor Signal Processing and Expert Reasoning (KASSPER) project with the goal of developing the first knowledge-aided (KA) real-time high performance embedded computing (HPEC).[5] Building on some of the pioneering work in knowledge-based and expert reasoning conducted at the AFRL's Rome Air Development Center (RADC),[11-13] the KASSPER project expanded

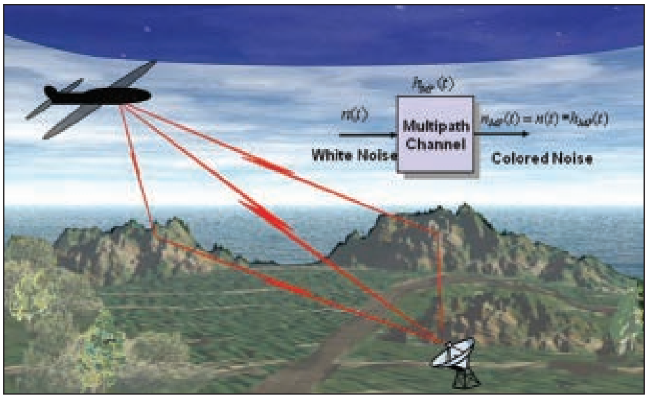


Fig. 4 Example of an additive colored noise source resulting from a multipath broadband interferer.[5]

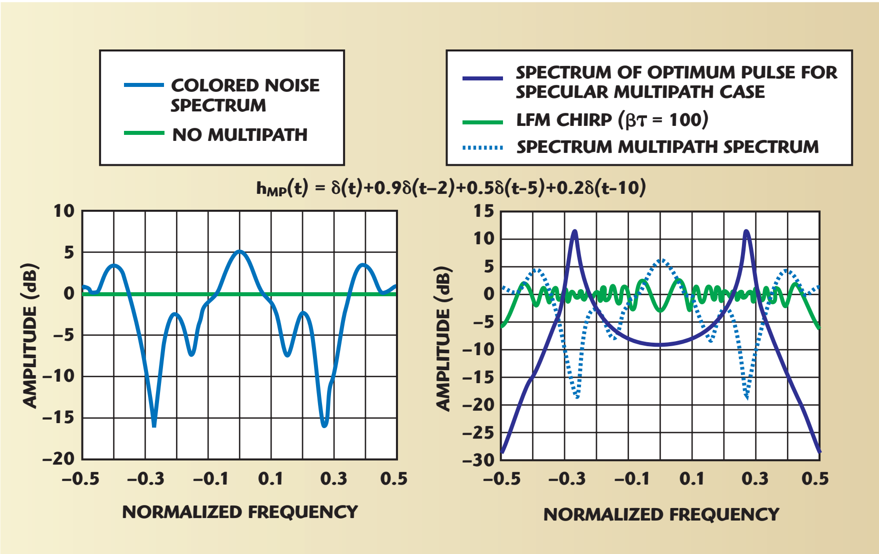


Fig. 5 Comparison of a non-adaptive (LFM) waveform and the optimum solution tailored to the interference spectrum.[5]

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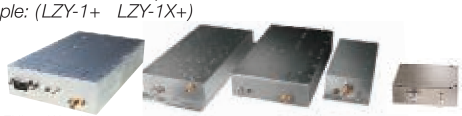
With Heat Sink/Fan										
LZY-1+	20-512	43	+45.7	+47.0	8.6	+54	26	7.3	1995	1895
LZY-2+	500-1000	46	+45.0	+45.8	8.0	+54	28	8.0	1995	1895
ZHL-5W-1	5-500	44	+39.5	+40.5	4.0	+49	25	3.3	995	970
ZHL-5W-2G+	800-2000	45	+37.0	+38.0	8.0	+44	24	2.0	995	945
ZHL-10W-2G+	800-2000	43	+40.0	+41.0	7.0	+50	24	5.0	1295	1220
ZHL-16W-43+	1800-4000	45	+41.0	+42.0	6.0	+47	28	4.3	1595	1545
• ZHL-20W-13	20-1000	50	+41.0	+43.0	3.5	+50	24	2.8	1395	1320
ZHL-30W-252+	700-2500	50	+44.0	+46.0	5.5	+52	28	6.3	2995	2920
• ZHL-50W-52	50-500	50	+46.0	+48.0	6.0	+55	24	9.3	1395	1320
• ZHL-100W-52	50-500	50	+47.0	+48.5	6.5	+57	24	10.5	1995	1920
NEW										
ZVE-3W-183+	5900-18000	35	+34.0	+35.0	5.5	+44	15	2.2	1295	1220
ZVE-3W-83+	2000-8000	36	+33.0	+35.0	5.8	+42	15	1.5	1295	1220
• ZHL-100W-GAN+	20-500	42	+49.0	+50.0	7.0	+60	30	9.5	2395	2320
ZHL-30W-262+	2300-2550	50	+43.0	+45.0	7.0	+50	28	4.3	1995	1920

• ***Protected under U.S. Patent 7,348,854***

*For models without heat sink, add **X suffix** to model No.*
Example: (LZY-1+ LZY-1X+)

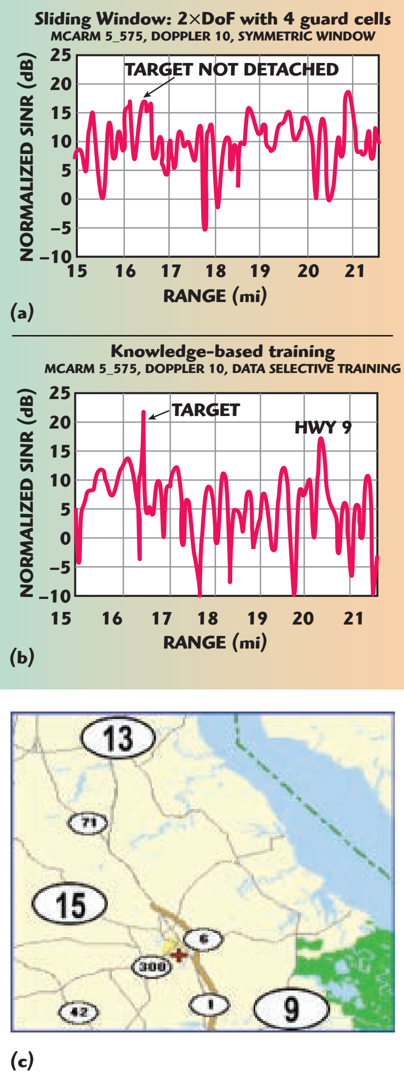


the algorithmic capabilities of KA processing and implemented a real-time version of KA STAP (space-time adaptive processing).[14]

STAP in real-world environments is particularly vulnerable to complex clutter environments due to its need to estimate a generally high dimensional space-time (such as angle-Doppler) covariance matrix. Using the "RMB Rule" (Reed, Mallett, Brennan)[15] to achieve a reasonable covariance estimate, an order of two times (2X) the dimension of the space-time receive vector is required for the number of independent and identically distributed (i.i.d.) training samples. For an eight element adaptive antenna, utilizing four Doppler channels (jointly), this results in the need for at least 32 i.i.d. samples. In most conventional STAP implementations, these samples are achieved by selecting 32 (or more) adjacent range bins to the range cell of interest. Dense target environments, highly heterogeneous terrain, urban clutter and other large clutter discretes can significantly degrade performance of a sample covariance based implementation of STAP.[6]

KA methods can overcome these issues by utilizing other information sources besides the incoming radar data stream. For example, it has been shown that digital terrain and land cover maps, SAR imagery (complex), and even prior measurement histories, can all be utilized to improve the estimation of the interference channel[5]—with commensurate improvements in radar performance. Generally, the incorporation of other knowledge sources into the adaptive filtering process is either direct or indirect. For example, an indirect method consists of a judicious selection of both the available training data and filter structure. Terrain and land cover maps are especially useful for this method as they can identify roadways, abrupt changes in terrain (such as land-sea interfaces), etc.

An example of the improvement achievable using an intelligent screening of the training data is displayed in ***Figure 6***. In this example, using AFRL's Multi-Channel Airborne Radar Measurement (MCARM) system, an airborne target becomes detectable after knowledge-



CELLS EXCLUDED	RATIONALE
135 – 14 MILES	RT. 15
16 – 17.5 MILES	RT. 13
19 – 20 MILES	RT. 9 IN SIDELOBE REGION, RADIAL ALIGNMENT
21 – 22 MILES	RT. 9 IN MAINLOBE

(d)

Fig. 6 Example of the effectiveness of indirect KA methods with real data.

aided training is applied to the STAP weights. In this particular example, competing ground traffic was causing a broadening of the angle-Doppler clutter notch.[16]

Direct methods of prior knowledge incorporation are generally more complex and difficult to implement, but can yield significantly improved performance in demanding environments. One example, grounded in the incorporation of "prior" information as formulated by Bayes,[17] is to com-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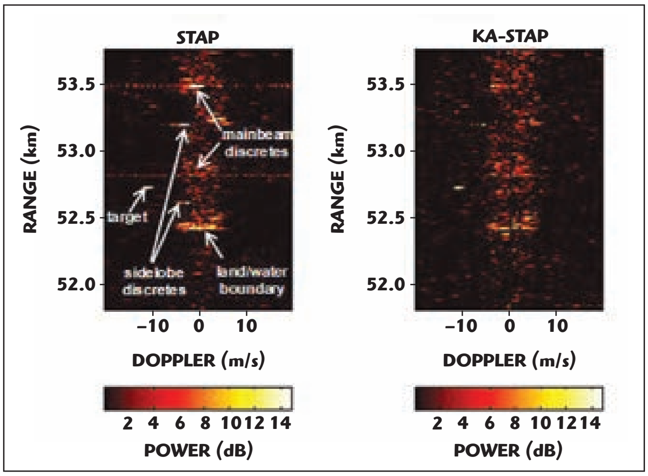
bine an estimate of the underlying clutter covariance matrix R obtained from prior knowledge sources $\hat{R}_o$, with an estimate $\hat{R}_d$ obtained using the incoming data stream. For example, under fairly general conditions, this KA estimate $\hat{R}_{KA}$ has the form

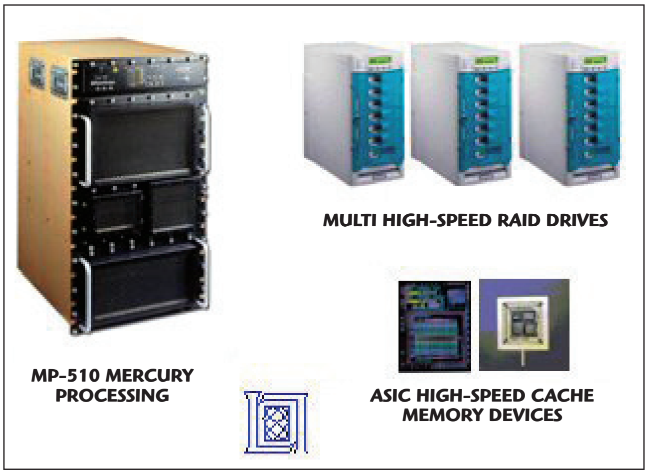
$$\hat{R}_{KA} = \alpha\hat{R}_o + \beta\hat{R}_d \qquad (9)$$

where typically α, β satisfy $0 \le \alpha \le 1$ and $\beta = 1 - \alpha$. The above was shown to be the optimum Bayesian estimate of the true underlying covariance R when $\hat{R}_o$ and $\hat{R}_d$ are statistically independent estimates (the weighting coefficients are simply proportional to the effective amount of training data used to form each constituent covariance estimate, respectively).[5] ***Figure 7*** shows an example of the performance improvements achievable using this type of direct method when applied to the 6th KASSPER data challenge set.[18] In this case, the prior knowledge source was a combination of digital terrain maps and an efficient electromagnetic propagation model. However, another extremely useful information source is SAR imagery, which is essentially a high resolution clutter map and thus ideally suited for creating KA priors.[5]

One of the biggest obstacles facing the DARPA/AFRL KASSPER project was not developing algorithms that could show the utility of incorporating other knowledge sources, but rather developing a real-time HPEC architecture that could overcome the inescapable latency associated with "retrieving data (knowledge) from memory". Somewhat surprisingly, the solution turned out to be relatively straightforward once an overall system engineering perspective was adopted relative to the types of radars involved.



▲ *Fig. 7 An example of the effectiveness of direct KA methods when applied to the 6th KASSPER Challenge data set.[18]*



▲ *Fig. 8 Real-time KASSPER HPEL system developed by MIT Lincoln Laboratories.*

The crux of the idea is this: The problem is accessing the environmental dynamic database (EDDB), which typically resides in some mass storage (such as RAID) configuration. This access cycle can take orders of magnitude more time than is required to keep up with real-time radar signal throughput timescales.[5]

However, this is where physics and engineering come in. If it were possible to know where the radar will be and what it will be doing, just a second or so in the future, a "look ahead" parallel processor (it is actually the KA co-processor of Figure 2), could begin the retrieval of relevant data and make any necessary adjustments (indirect or direct) to the baseline adaptive processing chain.[5] As it

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turns out, this assumption is perfectly justified in practice since: (1) An extremely accurate estimate (to within the radar's resolution) of the radar's position is typically available for many seconds into the future simply due to Newtonian physics; and (2) The radar scheduler is highly deterministic on the order of seconds (even longer in many cases). Thus, one can know where the radar will be, and what the radar will be doing far enough into the future to overcome the memory retrieval issues associated with KA processing. Indeed just such a real-time KASSPER architecture was built and demonstrated by MIT Lincoln Laboratories and displayed at DARPATech 2004 (see ***Figure 8***).[19]

PUTTING IT ALL TOGETHER: COGNITIVE RADAR

This article briefly introduces an emerging new adaptive sensor paradigm born out of two major radar advancements, transmit diversity/adaptivity, coupled with KA processing. When combined, an architecture emerges that can demonstrate all of the key attributes of a truly "cognitive" system. While radar was the focus of this article, it is hoped that other sensor and communication systems will benefit as well from a knowledge-aided, fully adaptive cognitive architecture. ■

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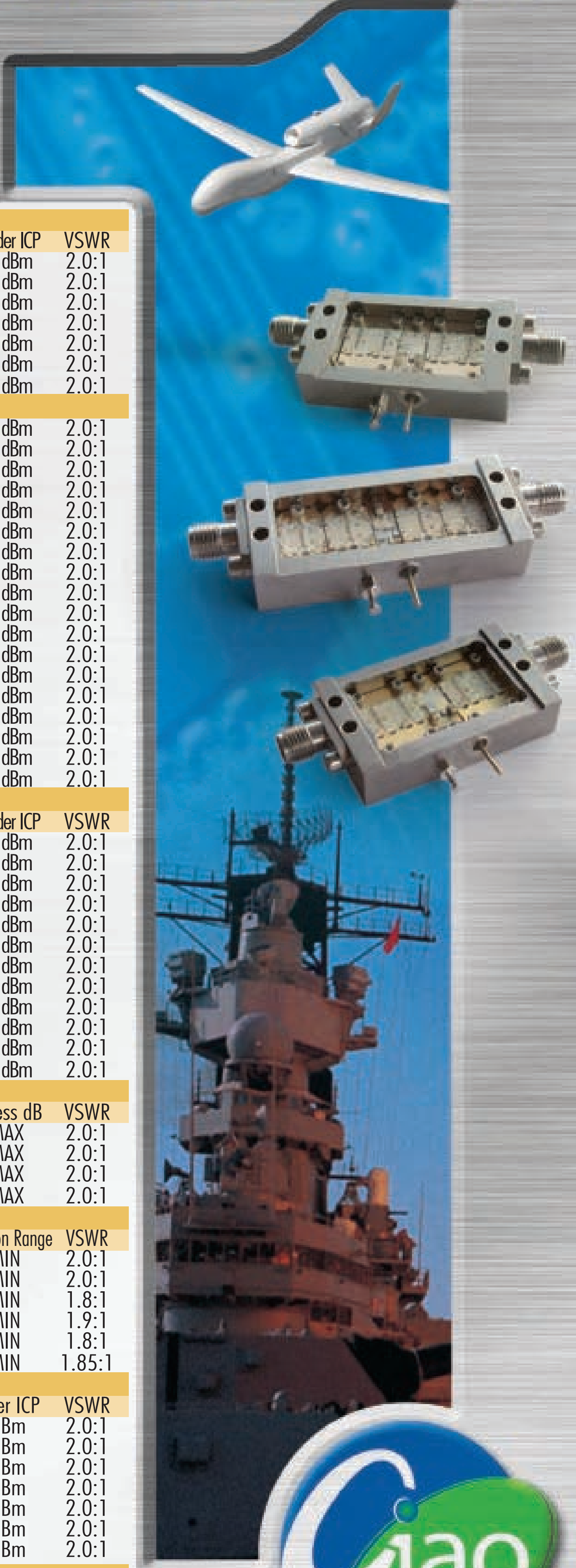

OCTAVE BAND LOW NOISE AMPLIFIERS

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

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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

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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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Raytheon Awarded AESA Radar Upgrade Contract for F-15C Aircraft

Raytheon Co. has received a contract from Boeing for the production of advanced APG-63(V)3 Active Electronically Scanned Array radars. The US Air Force and the US Air National Guard will receive radars from the contract and deliveries will begin in the second quarter of 2011. The radars are intended to enhance the performance of deployed F-15C aircraft and will replace the current mechanically scanned radar systems. With its superior targeting and tracking capabilities, the APG-63(V)3 will enable aircrews to detect and identify targets well beyond the range of the existing systems.

"Our APG-63(V)3 AESA radars offer significant reliability and maintainability benefits, resulting in lower life-cycle costs," said Steve Schwarzkopf, F-15 Program Director, Tactical Airborne Systems. "These systems are designed to give pilots the ultimate operational advantage and bring them home safely."

Harris Corp. Receives $21 M in Orders from US Marine Corps for Falcon III AN/PRC-117 G

Harris Corp., an international communications and information technology company, has received orders from the US Marine Corps totaling $21 M for additional Falcon III AN/PRC-117G multiband manpack radios, vehicular amplifier adapters and other accessories. The Marine Corps will acquire the systems as part of its accelerating transition to high-speed, wideband networked tactical communications. The orders were received in July, August and September.

The AN/PRC-117G is the first JTRS Software Communications Architecture (SCA)-certified and NSA Type-1 certified wideband manpack radio system.

The AN/PRC-117G radio provides warfighters with unprecedented situational awareness of the battlefield by enabling applications such as streaming video, simultaneous voice and data feeds, collaborative chat, and connectivity to secure networks. The wideband networking capabilities of the AN/PRC-117G give warfighters critical real-time information through a man-portable radio that is smaller, lighter and more capable than legacy units. The AN/PRC-117G is the first JTRS Software Communications Architecture (SCA)-certified and NSA Type-1 certified wideband manpack radio system.

"The continued deployment of the AN/PRC-117G radio will provide more Marines with the advanced interoperable communications they need for current and future mission success," said Brendan O'Connell, President, Department of Defense business, Harris RF Communications. "The radio expands the availability of next-generation combat applications that will result in better coordination and communication in the heat of battle. In addition, AN/PRC-117G is software-defined, offering the flexibility to continuously and rapidly deliver on evolving requirements and emerging mission needs."

The AN/PRC-117G is also upgradeable via new Harris Mission Modules, which provide additional functionality such as a second wideband channel. The Mission Modules attach to the AN/PRC-117G through an open, standardized and interchangeable architecture. This allows users to take only the capabilities they need into the field, while optimizing size, weight and power capabilities. The Falcon III AN/PRC-117G and the entire Falcon III® family of radios are becoming the standard for advanced tactical communications throughout the world, having been widely adopted by the US Department of Defense, federal agencies and key allies such as Canada, the United Kingdom and Australia. The AN/PRC-117G manpack radio was developed following the US Joint Tactical Radio System (JTRS) program's Enterprise Business Model (EBM). The EBM encourages companies to develop next-generation solutions in tactical communications using their own investment capital. In doing so, the EBM encourages competition, increases innovation, reduces costs and speeds development of important capabilities.

Lockheed Martin – Raytheon Team Competes for Ground-based Midcourse Defense Contract

Lockheed Martin announced that the Lockheed Martin-Raytheon team competing for the Ground-based Midcourse Defense (GMD) Development and Sustainment Contract has received the final request for proposal from the US Missile Defense Agency (MDA). MDA issued the request for proposal December 2, with a submission due date of January 28. The contract will continue development, manufacturing, test, training, operations support and sustainment support of the GMD element of the Ballistic Missile Defense System, which protects the nation, its allies and friends against limited ballistic missile attack.

"This team is prepared and enthusiastic about our offer to support this critical national asset…"

"This team is prepared and enthusiastic about our offer to support this critical national asset," said Mathew J. Joyce, GMD Vice President and Program Manager, Lockheed Martin Space Systems Co. "Backed by proven performance and domain expertise, our bid will assure a smooth

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transition. The entire Lockheed Martin-Raytheon team is dedicated to a transparent partnership with the MDA and GMD program office." Lockheed Martin will be prime contractor and systems integrator.

In addition to the GMD Exoatmospheric Kill Vehicle, Raytheon will provide systems engineering, development, modeling and simulation, operations and sustainment, manufacturing, testing and training. "Three additional companies have joined our best-of-industry team," said Joyce. Bluespring Software will provide software tools for modeling, analysis and process improvement. Mission Solutions Engineering will provide systems engineering and software development support. Raytheon Trusted Computer Solutions will provide software support services.

Raytheon Awarded $240 M for Aegis Production

The US Navy awarded Raytheon Co. $240 M for production and delivery of critical components of the Aegis weapons system for the Arleigh Burke class of destroyers. Under the contract, Raytheon Integrated Defense Systems (IDS) will provide production, engineering and support services for four ship sets of the AN/SPY-1D(V) transmitter group and MK99 Mod 8 Fire Control System. The radar and fire control system equipment is essential to the Aegis weapon system's ability to track and defend against multiple threats, including planes and missiles.

"Raytheon's naval radar components are providing extensive capabilities and proven performance for Aegis-equipped ships worldwide," said Raytheon IDS' John Kelly, Director of Sensor Systems. "This current contract continues Raytheon's legacy as a key contributor to the Aegis program and as an industry leader in the design and development of naval radars."

"Raytheon's naval radar components are providing extensive capabilities and proven performance for Aegis-equipped ships worldwide…"

Raytheon's AN/SPY-1 radar transmitters and MK99 Fire Control System have been in continual production for 30 years as part of the US Navy's Aegis shipbuilding program. The AN/SPY-1 and the MK99 are currently installed in the US Navy's fleet of Ticonderoga-class cruisers and Arleigh Burke-class destroyers, as well as in Japanese Kongo-class destroyers and Spanish F100-class frigates.

Work on the Aegis program is performed at Raytheon IDS' Surveillance and Sensors Center, Sudbury, MA, at the Seapower Capability Center, Portsmouth, RI, and at the Integrated Air Defense Center, Andover, MA. The $240 M contract contains options for additional work.


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Ministers Endorse Resolution to Deliver European Space Strategy

Ministers in charge of space activities representing the Member States of the European Space Agency (ESA) and the European Union who convened in Brussels for the Seventh Space Council unanimously endorsed a resolution that called for the necessary actions to deliver a space strategy that would enable economic growth, respond to public policy objectives, and develop the vocations of science and technology in Europe.

Ministers emphasised that the flagship programmes Galileo and Global Monitoring for Environment and Security (GMES) remain the priorities for the EU in space and identified the key decisions to be taken in these areas over the coming months. In the areas of Global Climate Change and Security, the ministers asked the European Commission and the Director General of ESA to collaborate with the Member States and other relevant players in Europe to identify how to fill gaps in existing space capabilities.

…the flagship programmes Galileo and GMES remain the priorities for the EU in space…

Ministers also recognised the need to move towards establishing a Space Situational Awareness capability for the protection of Europe's space assets. They stressed the need for Europe to voice a single European position in international discussions on space exploration.

ESA Director General Jean-Jacques Dordain emphasised the progress that had been achieved in space missions since the previous Space Council meeting in May 2009, commenting: "The entry into force of the Treaty on the Functioning of the European Union, with a specific space competence, is good news for space, good news for Europe and good news for ESA. It allows us not to do the same thing differently but to do more, together."

Asia Pacific LTE Connections to Surpass 120 Million by 2015

The number of LTE connections in Asia Pacific will exceed 120 million by 2015, according to the latest data released by Wireless Intelligence. This aggressive growth will be spearheaded by China with the country expected to account for nearly half (57.9 million) of the total number of LTE connections in Asia Pacific during this period.

The data shows that behind China, the three largest LTE markets in Asia Pacific in 2015 will be: Japan with 26.5 million connections; Indonesia with 13.1 million connections; and South Korea with 9.8 million connections. Significant growth is also anticipated in other leading Asia Pacific countries, including Australia, Malaysia, the Philippines and Taiwan, as mobile operators and vendors embrace the additional capacity and enhanced throughput for next-generation Mobile Broadband services that LTE offers.

Joss Gillet, Senior Analyst, Wireless Intelligence, stated, "The introduction of high-speed LTE will increase demand for mobile Internet and Mobile Broadband in Asia Pacific. Among many possible adoption scenarios, the release of digital dividend spectrum will play an important role in connecting consumers to these new networks."

China's major operators, including China Mobile and China Unicom, are backing LTE. Following its recent test network deployment at Shanghai World Expo, China Mobile will begin the construction of TD LTE pilot networks to test the technology in major Chinese cities in 2011. China Unicom is due to conclude LTE trials in 2011 and China Telecom is also likely to launch LTE in the future. The supporting ecosystem for TD LTE technology continues to build globally, driving economies of scale for other operators. TD LTE technology is set for deployment in India and is also attracting the attention of WiMAX operators in the US who are contemplating LTE migration in the future.

…aggressive growth will be spearheaded by China…

The countries expected to drive the Asia Pacific LTE market currently have a strong HSPA and HSPA+ installed base from which to migrate. According to the latest statistics from Wireless Intelligence, there are 120 million HSPA connections in the Asia Pacific region. The largest HSPA markets in Asia Pacific currently include South Korea with 30 million connections, Japan with 28 million, Australia with 13 million and China with 10 million.

DMR Association and ETSI Post Their Intentions

The Digital Mobile Radio (DMR) Association and the European Telecommunications Standards Institute (ETSI) have signed a letter of intent to cooperate in the area of Digital Mobile Radio and to work together for their mutual benefit. The letter of intent—signed by Dr. Walter Weigel, ETSI's Director General, and by Mario Micheli, Chairman of the DMR Association—marks the beginning of various co-operative activities in the field of DMR systems, including the exchange of knowledge and expertise, with a specific focus on DMR standardization activities.

"…the letter of intent represents a significant milestone in the DMR Association's long-term strategy…"

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"As DMR's standardization body we value the opportunity to develop a mutually beneficial relationship with the DMR Association. A healthy exchange of vital market feedback and product development experiences will allow us to better address the requirements for future evolutions of the DMR standard," commented Weigel.

Micheli agreed, saying, "This step is the best route to achieve the common objective of ensuring that DMR technology will represent a success story for both organizations. The signing of the letter of intent represents a significant milestone in the DMR Association's long-term strategy of promoting the success of DMR technology by removing barriers to interoperability and supporting continuous product innovation."

£2 M Space Innovation Competition is Launched

The UK's Technology Strategy Board (TSB) and the South East England Development Agency (SEEDA) have launched a £2 M funding competition to stimulate innovation across the space industry. The Feasibility Studies for Innovation in Space funding competition aims to accelerate the development of new innovative commercial opportunities in the space sector and is aimed at innovative businesses in the UK, with investment of up to £25,000 available for each feasibility study.

The key criteria for assessment of project proposals from companies will be market potential, commercial impact and potential for success in the next steps of development. Project proposals must relate to one or more of the following market areas: Satellite Telecommunications; Sensing; Position, Navigation & Timing; Robotics & Exploration and Access to Space.

Projects are strongly encouraged to exploit and build on the capability of the International Space Innovation Centre, a centre of excellence and hub for British space activity, which SEEDA has supported with £6 M of collaborative R&D funding. The competition opens on 10 January 2011 and closes on 10 February 2011. The feasibility studies supported under this competition may develop into submissions to a follow-on competition, which is under consideration for later in 2011.

The... competition aims to accelerate the development of new innovative commercial opportunities in the space sector...

For more information, visit: www.innovateuk.org/_assets/pdf/competition-documents/briefs/tsb_feasibilitystudiesforinnovationinspace.pdf.

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IF/RF MICROWAVE COMPONENTS

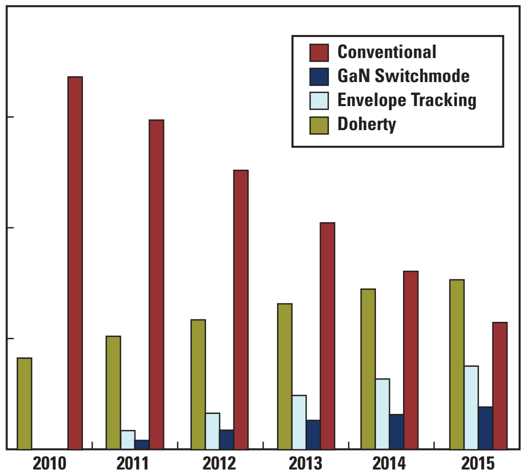
Dan Massé, Associate Technical Editor

TD-SCDMA, China and GSM Still Lead RF Power Amplifier and Device Markets

Rapid Chinese TD-SCDMA rollouts and the often-maligned GSM/GPRS/EDGE equipment markets have benefited the base station RF power amplifier and RF power device markets. GSM/GPRS/EDGE RFPAs and devices are still shipping in the millions. The Asia-Pacific region is presently accounting for more than 50 percent of the RF power semiconductor devices sold into the mobile wireless infrastructure segment.

Recent Chinese TD-SCDMA base station deployments have been massive, and have buoyed RF power vendors to a tremendous degree. That demand is expected to strengthen the market until at least sometime in 2011, and the Chinese deployments will probably only start to slow in 2012. And in a happy coincidence for equipment vendors, 2011 is the expected time frame for LTE deployments in developed countries to really gather a head of steam.

Cellular/Mobile Wireless Infrastructure PA Revenue for Conventional vs. High-Efficiency World Market: 2010–2015



Source: ABI Research

LTE Subscriber Growth Will Approach Nearly 115 Million by 2014

While LTE is destined to become the dominant wireless airlink, several formidable challenges will make its widespread adoption slower than many expect. For starters, spectrum has to be cleared, licensed and either allocated or sold off before LTE takes hold. As every country has its own telecommunications regulations, these factors will take varying periods of time to be resolved. However, despite this difficult path, In-Stat forecasts that the number of LTE subscribers will approach 115 million by 2014.

"US operator LTE CAPEX spending will drive wireless leadership from Asia and Europe to North America," says Chris Kissel, Industry Analyst for In-Stat. "From 2009 to 2014, more than one quarter of global LTE CAPEX spending will occur in the US. As a result, the US will have more LTE subscribers than the entire Asia/Pacific region by the end of 2014, even though it will have less than half the POPs."

"US operator LTE CAPEX spending will drive wireless leadership from Asia and Europe to North America…"

Recent In-Stat research found the following:

- Although the vast majority of LTE subscribers will be FDD-LTE, TD-LTE will have a CAGR through 2014 of almost twice that of FDD-LTE.
- Working through technology partners, Huawei and Ericsson, Vodafone purchased 1,500 LTE base stations in Germany in 2010.
- LTE networks will have better than half of all last mile backhaul capacity in North America by 2014.
- Despite the potential for LTE services in China and India, Japan is very likely to have the most LTE subscribers in Asia/Pacific by the end of 2014.

Microwave the Favored Backhaul Solution for Western Europe and Much of Asia-Pac

Capital expenditure on mobile backhaul varies greatly by region and by technology. While most countries face similar current or future struggles to reduce network congestion, the solutions being adopted differ according to existing infrastructure, network generations, and government mandates and incentives. One major division is whether to use optic fiber or microwave for mobile backhaul. CAPEX for microwave backhaul will peak in Western Europe this year at almost $4.4 B, more than triple the figure for the next-highest region, Asia-Pacific. The European spending surge is due to the expansion of 3G networks to new areas, as well as a few initial 4G network deployments.

CAPEX for microwave backhaul will peak in Western Europe this year at almost $4.4 B…

"Once that wave is completed in Western Europe, microwave backhaul will be left alone for a while," comments ABI Research Analyst Xavier Ortiz. "Following the 2010 spending spree, Western European microwave backhaul CAPEX will tumble in 2011 to just over half its peak level."

Virtually all world regions will see some increase in microwave backhaul CAPEX over 2011-2013, followed by

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a gradual decline. The reasons vary by location. In Asia, many 3G networks will be rolled out during that period, and others will be expanded to reach remote, underserved areas. According to Practice Director Aditya Kaul, "Asia's investment in microwave backhaul would be even greater were it not for the Chinese government's mandate to use fiber for the country's 3G and 4G networks. Although microwave is less expensive and faster to deploy, a governmental commitment to fiber means huge economies of scale, and fewer worries about zoning permissions." In the United States, the situation is very different. The prevalence of fiber optic cable in many parts of the country combined with the high cost of tower leasing mean that interest in microwave as a backhaul solution is lower than anywhere else. "Large service providers are saying they will only use microwave where fiber is unavailable," says Ortiz.

Nearly Half of Smartphone Owners Use Phones for Mobile Shopping

A recent survey of 2,000 consumer technology users conducted by ABI Research in the United States has revealed that nearly half of smartphone users say they have already, or soon will, use their phones to do mobile shopping. Fifty-three percent also use, or intend to use, their smartphones for mobile banking. "These are very exciting findings for merchants and service providers promoting mobile commerce," says Senior Analyst Mark Beccue. "We see mobile commerce in the US finally starting to achieve a mass market appeal. It's not just smartphone owners: non-smartphone mobile users' interest in mobile banking and commerce services, while lower than that among smartphone owners, is also on the rise, with 17 percent of non-smartphone users surveyed using or intending to use mobile banking services."

> ***"We see mobile commerce in the US finally starting to achieve a mass market appeal."***

"These findings are part of a larger picture which quantifies smartphone users' consistently higher use of a wide range of activities and features, from mobile browsing through multimedia to navigation," notes primary Research Director Janet Wise. "Smartphone users behave differently. They score higher for all these activities 'because they can' (their devices are capable), and also because they have the money, resources and time to do all these things."

Mobile Market Strategies Practice Director Neil Strother adds, "Even advertising holds a growing attraction for mobile phone users, with about one third of those smartphone owners surveyed saying they have clicked on at least one mobile advertisement."

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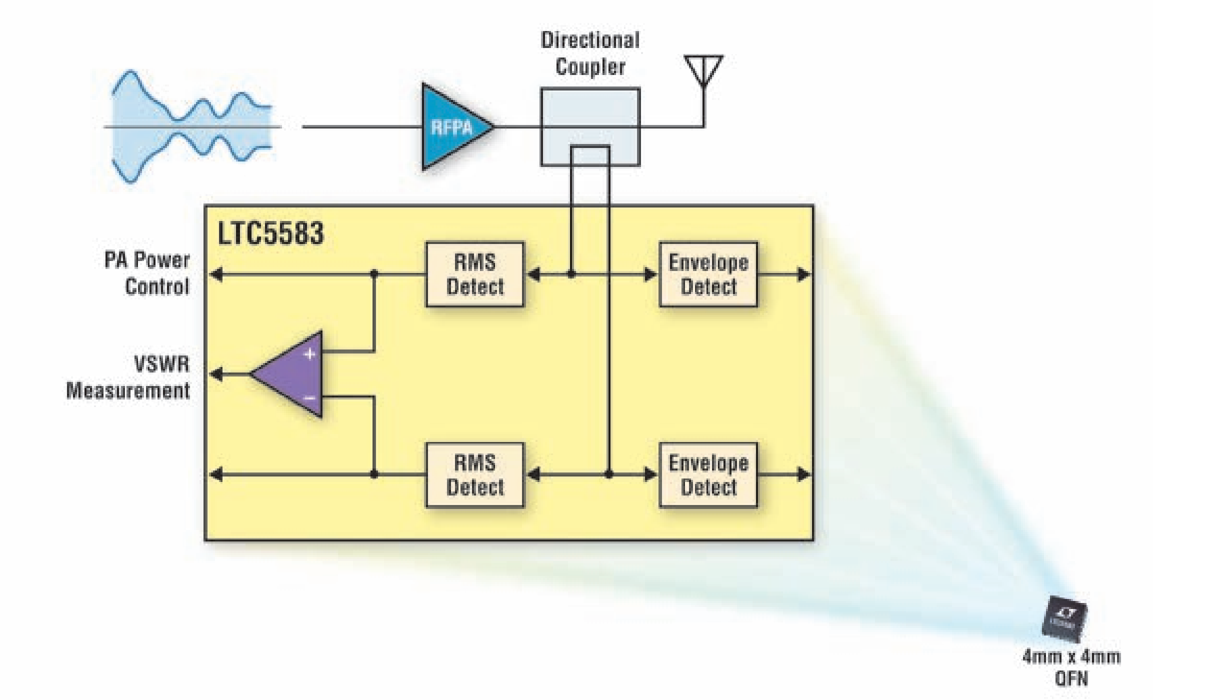

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Dynamic Range (dB)	60	57	40	40
Detection Range (dBm)	–58 to 2	–56 to 1	–34 to 6	–34 to 6
Measurement Accuracy (–40°C to 85°C)	±0.5dB	±0.5dB	±1dB	±1dB
Output Interface	Log-Linear Voltage	Log-Linear Voltage	Log-Linear Voltage	12-Bit Serial ADC
Power Supply	3.3V/90mA	3.3V/42mA	3V/1.4mA	3.3V/3mA

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Around the Circuit

Jennifer DiMarco, Staff Editor

INDUSTRY NEWS

Agilent Technologies Inc. announced it has acquired certain assets of **Signametrics**, a manufacturer of PXI, VXI, PCI and USB digital multimeters (DMM), and modular switching products. These test and measurement products are commonly used in manufacturing production and automotive test systems. The acquisition expands Agilent's current offering in DMMs and data acquisition and switching solutions.

CPI International Inc. announced the signing of a definitive merger agreement under which CPI International (CPI) will be acquired by an affiliate of Veritas Capital Fund IV (Veritas Capital) for $19.50 per share in cash. The purchase price reflects a premium of approximately 35 percent over the closing price of CPI common stock on November 24, 2010, and 38 percent over the average closing price of CPI common stock for the 90 days ending November 24, 2010. The transaction is valued at approximately $525 M.

Microsemi Corp., a manufacturer of high performance analog-mixed signal integrated circuits, high reliability semiconductors and RF subsystems, announced the successful completion of its tender offer, through its wholly owned subsidiary Artful Acquisition Corp., for all outstanding shares of **Actel Corp.** Based upon information provided by Wells Fargo Bank, N.A., the depositary for the tender offer, approximately 23.1 million shares, representing approximately 87.9 percent of Actel's outstanding shares, were validly tendered and not withdrawn in the offer, together with an additional 860,000 shares tendered by notice of guaranteed delivery. Artful Acquisition Corp. accepted for payment all such validly tendered shares. Microsemi does not intend to offer a subsequent offering period in connection with the offer.

Fairchild Semiconductor, long-acknowledged as a power semiconductor leader, is increasing its focus on the mobile handset market. The company is building on its success in the development of semiconductor solutions that deliver new levels of functionality to help differentiate mobile designs. Fairchild creates feature-specific semiconductor products that complement chip sets in mobile devices. It is increasing investment in and development of a targeted portfolio of analog and power intellectual property (IP) to support handset manufacturers' specific signal path requirements.

Technical Research and Manufacturing Inc., a global leader in the design and manufacturing of passive RF and microwave components, is announcing the changing of its name to **TRM Microwave** and the launch of its new website, www.trmmicrowave.com.

RF Micro Devices Inc. (RFMD), a leader in the design and manufacture of high performance radio frequency components and compound semiconductor technologies, announced the company has added its world-class Gallium Arsenide (GaAs) technology to RFMD's foundry services portfolio and will begin providing a full suite of GaAs Pseudomorphic High Electron Mobility Transistor (PHEMT) technologies to customers of its Foundry Services business unit. Specifically, RFMD will make available three distinct GaAs PHEMT technologies optimized for high power, low noise and RF switching products.

Tektronix Service Solutions, a single-source provider of instrument calibration, repair and related services, announced the expansion of services into Canada with a new service lab in Mississauga, Ontario. The expansion provides enhanced service options and added flexibility for companies that rely on their test, measurement and control instrumentation for day to day operations. Tektronix Service Solutions' new facility is located at 400 Britannia Road East, Unit 2, Mississauga, ON L4Z 1X9.

M/A-COM Technology Solutions Inc. announced that its Santa Clara Design Center has moved to a new facility with state-of-the-art equipment to accommodate the expanded engineering and business functions that occur at this location. This Design Center is focused on the design and development of monolithic PHEMT integrated solutions covering 6 to 50 GHz for commercial and military applications. M/A-COM Tech had previously announced in May 2010 that Henrik Morkner joined the company as Director of Engineering to lead this team in Santa Clara, and this expansion points to the group's commitment to collaborating with its marketing teams and customers to develop industry-leading devices. The new Santa Clara Design Center occupies approximately 11,600 square feet and includes a 1,200 square foot engineering lab for design and test characterization of MMICs, surface-mount devices (SMD) and connectorized modules.

Renaissance Electronics Corp./HXI announced that **HXI** has moved to the corporate headquarters in Harvard, MA. The new address is 12 Lancaster County Road, Harvard, MA 01451 and the phone number is (978) 772-7774. Web and e-mail addresses remain the same.

IKE Micro, and its sister company **Bonding Source**, have moved into a newly refurbished facility, doubling their capacity. The 14,000 square foot IKE Micro facility includes a 3,200 Class 10,000 clean room, ESD flooring in the clean room and SMT areas, a larger material handling area for additional turnkey business, and proprietary manufacturing areas. IKE has also installed a high end Palomar 8000 automatic ball bonding machine. The expanded Bonding Source facility includes an area for monitored freezers and a clean room for the laser cutting of epoxy pre-forms.

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DCO50100-5	500 - 1000	0.5 - 15	+5 @ 34 mA	-100	0.3 x 0.3 x 0.1
DCO6080-3	600 - 800	0 - 3	+3 @ 15 mA	-105	0.3 x 0.3 x 0.1
DCO7075-3	700 - 750	0.5 - 3	+3 @ 12 mA	-108	0.3 x 0.3 x 0.1
DCO80100-5	800 - 1000	0.5 - 8	+5 @ 26 mA	-111	0.3 x 0.3 x 0.1
DCO8190-5	810 - 900	0.5 - 16	+5 @ 34 mA	-118	0.3 x 0.3 x 0.1
DCO100200-5	1000 - 2000	0.5 - 24	+5 @ 36 mA	-95	0.3 x 0.3 x 0.1
DCO1198-8	1195 - 1205	0.5 - 8	+8 @ 30 mA	-115	0.3 x 0.3 x 0.1
DCO170340-5	1700 - 3400	0.5 - 24	+5 @ 29 mA	-90	0.3 x 0.3 x 0.1
DCO200400-5 DCO200400-3	2000 - 4000	0.5 - 18	+5 @ 46 mA +3 @ 46 mA	-90 -89	0.3 x 0.3 x 0.1
DCO300600-5 DCO300600-3	3000 - 6000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-80 -78	0.3 x 0.3 x 0.1
DCO400800-5 DCO400800-3	4000 - 8000	0.5 - 18	+5 @ 20 mA +3 @ 20 mA	-78 -76	0.3 x 0.3 x 0.1
DCO432493-5 DCO432493-3	4325 - 4950	0.5 - 11	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.1
DCO473542-5 DCO473542-3	4730 - 5420	0.5 - 22	+5 @ 20 mA +3 @ 20 mA	-88 -86	0.3 x 0.3 x 0.1
DCO490517-5 DCO490517-3	4900 - 5175	0.5 - 5	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.1
DCO495550-5 DCO495550-3	4950 - 5500	0.5 - 12	+5 @ 22 mA +3 @ 22 mA	-83 -85	0.3 x 0.3 x 0.1
DCO579582-5	5780 - 5880	0.5 - 10	+5 @ 20 mA	-90	0.3 x 0.3 x 0.1
DCO608634-5 DCO608634-3	6080 - 6340	0.5 - 5	+5 @ 20 mA +3 @ 26 mA	-85 -86	0.3 x 0.3 x 0.1
DCO615712-5 DCO615712-3	6150 - 7120	0.5 - 18	+5 @ 22 mA +3 @ 22 mA	-85 -83	0.3 x 0.3 x 0.1

Model	Frequency Range (GHz)	Tuning Voltage (VDC)	DC Bias VDC @ I [Typ.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]	Size (Inch)
DXO Series					
DXO810900-5 DXO810900-3	8.1 - 8.925	0.5 - 15	+5 @ 32 mA +3 @ 32 mA	-82 -80	0.3 x 0.3 x 0.1
DXO900965-5 DXO900965-3	9.0 - 9.65	0.5 - 12	+5 @ 27 mA +3 @ 27 mA	-80 -78	0.3 x 0.3 x 0.1
DXO10701095-5	10.70 - 10.95	0.5 - 15	+5 @ 25 mA	-82	0.3 x 0.3 x 0.1
DXO11441200-5	11.44 - 12.0	0.5 - 15	+5 @ 30 mA	-82	0.3 x 0.3 x 0.1
DXO11751220-5	11.75 - 12.2	0.5 - 15	+5 @ 30 mA	-80	0.3 x 0.3 x 0.1

Features

- Exceptional Phase Noise
- Dimensions: 0.3" x 0.3" x 0.1"
- Excellent Tuning Linearity
- Models Available from 4 to 12 GHz
- High Immunity To Phase Hits
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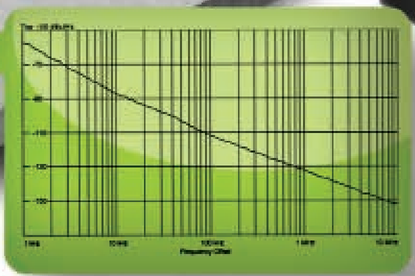
- Patented Technology



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RoHS COMPLIANT

Bonding Source has purchased a CO_2 laser machine that will be installed in February 2011.

Remcom announced a new partner in its program to provide custom computer systems for speeding FDTD electromagnetic simulation performance. **Exxact Corp.** develops and manufactures innovatively engineered high performance systems for graphics processing unit (GPU) computing, professional workstation, visual computing and other applications. The company's custom configured systems include the most modern GPU technology available today and can run XFdtd® simulations at speeds orders of magnitudes faster than traditional hardware.

Samsung Telecommunications America (Samsung Mobile) and **Cellular South** announced their collaboration to build and deploy a fourth generation (4G) mobile broadband network using Long Term Evolution (LTE) technology. The agreement also calls for Samsung Mobile to design and launch two LTE-enabled smartphone handsets available in 2011 in Cellular South's 700 MHz footprint.

Giga-tronics announced that Giga-tronics Inc. and **Advanced Test Equipment Rentals** (ATEC) partnered to offer lease and rental of Giga-tronics' high-end RF and microwave test and measurement equipment. ATEC, a leader in electronic test equipment asset management, will provide rental and leasing of Giga-tronics RF and microwave test solutions, including fast-switching microwave signal generators, microwave power amplifiers, and high-accuracy power meters and sensors. The partnering agreement will include options for integrated promotion, advertising and sales of test solutions. ATEC will be able to access the US market with the Giga-tronics sales channel and Giga-tronics will be able to supply its products for rental, lease and distribution through ATEC.

Agilent Technologies Inc. announced that **Moray Rumney**, the lead technologist specializing in LTE at Agilent, has won the Informa LTE North America 2010 award for individual contribution to LTE development. The Informa LTE North America Awards recognize and celebrate excellence in the LTE community. The nine awards categories cover LTE standards, product design and network deployment, plus the individual contribution award. Rumney's work is centered around radio standardization at 3GPP RAN WG4 and more recently at the LTE/SAE Trial Initiative where he helped develop LTE field trial tests. A frequent presenter and chair at wireless industry conferences, he has published many technical articles, hosted web seminars and edited *LTE and the Evolution to 4G Wireless*. His current standards work includes development of antenna testing methods for LTE MIMO user equipment, and he is working with other Agilent LTE experts on the second edition of Agilent's LTE book, which will include 4G LTE-Advanced.

Rogers Corp. announced that it has signed an agreement with **PolyWorks Corp.**, North Smithfield, RI, to license PolyWorks' technology for molding Rogers' industry-leading high performance foam brand, PORON microcellular polyurethanes, into three-dimensional shapes. The agreement, finalized on November 2, 2010, stems from a multi-year joint development effort to adapt PolyWorks' molding technology to PORON materials technology, enabling Rogers to expand its PORON urethane offerings beyond its traditional continuous sheet form. It calls for Rogers to acquire a custom molding machine from PolyWorks and a license to utilize PolyWorks' technology for the molding of PORON formulations.

Maxim Integrated Products recently qualified and shipped production analog product built on 300 mm wafers. This gives Maxim a significant technology edge in the analog/mixed-signal market. Maxim is now producing 300 mm wafers using its state-of-the-art 180 nm BCD analog process technology (S18) in Powerchip Technology Corp.'s wafer fab through a foundry agreement. This achievement gives Maxim a strategic advantage in the analog market, providing a capital-efficient manufacturing model that enables quick response to changing market conditions. It extends Maxim's hybrid approach to wafer fab capacity, utilizing both in-house and outsourced wafer fabrication.

CONTRACTS

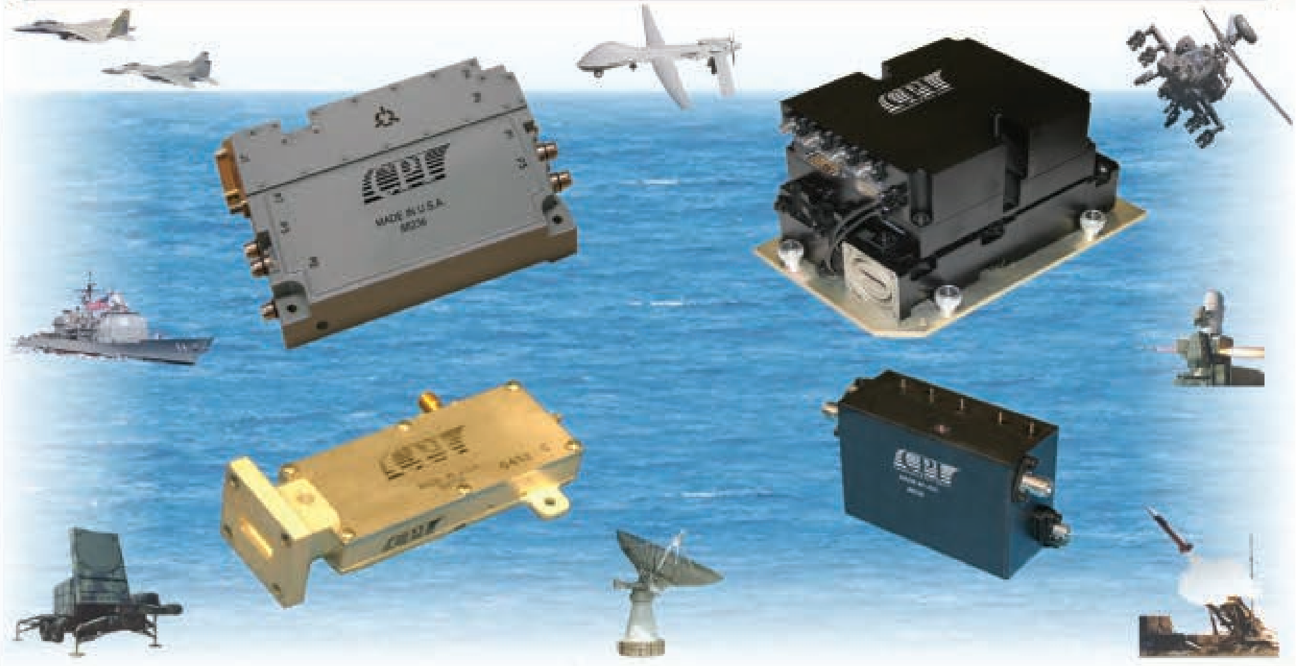
The US Department of Defense is awarding **Raytheon** a $52.25 M contract modification for 19 APG-79 active electronically scanned array (AESA) radars to be retrofitted into F/A-18E/F aircraft, Lots 26-29. The APG-79 AESA radar, which will replace the APG-73 radar, will provide increased air-to-air detection and track range, increased air-to-ground targeting capabilities, longer launch range for standoff weapons, enhanced capability against advanced threats, and optimized utilization of the Super Hornet's weapons systems. The contract was awarded to Raytheon Space and Airborne Systems of El Segundo, CA. Work will be performed in Forest, MS (43 percent); Dallas, TX (29 percent); El Segundo, CA (27 percent); and Andover, MA (1 percent), and is expected to be completed in December 2013.

Harris Corp., an international communications and information technology company, has received orders from the US Marine Corps totaling $21 M for additional Falcon III® AN/PRC-117G multiband manpack radios, vehicular amplifier adapters and other accessories. The Marine Corps will acquire the systems as part of its accelerating transition to high-speed, wideband networked tactical communications. The orders were received in July, August and September.

Anaren Inc. has been selected to receive a contract valued in excess of $20 M from **Thales-Alenia-Space** (France) for development and production of integrated beamforming assemblies that will be deployed on the IridiumNEXT satellite payload. The contract award, expected to be finalized within 90 days, covers design services and manufacture of up to 81 beamforming networks. Work has been authorized to begin immediately, with production deliveries starting in October 2012.

ITS Electronics Inc. announced an initial $4 M contract with **TECOM Industries Inc.** to supply its High Power Transceiver-HPT that will enable the antenna system for a major commercial carrier's new onboard Wi-Fi service.

Integrated Microwave Assemblies



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Communications & Power Industries' Beverly Microwave Division (BMD) offers product technology that includes Integrated Microwave Assemblies and Control Components. BMD's broad experience and extensive capabilities in the areas of high power microwave component design for military and non-military radar, satellite, communications, and EW systems makes it uniquely suited to design and manufacture a wide range of components and multi-function assemblies in small, lightweight packages. Coupling that with our experience in other transmission lines and technologies gives us a technical capability that is unparalleled in the microwave industry.

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* Power handling to 1 MW+ peak
* Integral driver & associated electronics
* The industry's most extensive high power test facility

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TECOM's KuStream™ 1000 antenna system is being installed on the carrier's fleet of more than 500 aircraft. Equipage has begun at a rate of 15 aircraft per month, and will ultimately expand to 25 aircraft per month.

Herley Industries Inc. announced that its **Micro Systems Inc.** subsidiary in Fort Walton Beach, FL, has been awarded \$3 M in contracts to accomplish changes to its aerial target ground control stations and airborne avionics for a US Navy customer. The contracts require a change in operating frequency and a major update to the company's ground control station hardware to transition to the use of laptop computers to replace aging custom designed target and master control consoles. The change in operating frequency is directed at minimizing interference issues that are sometimes encountered with the existing systems.

Integral Systems Inc. announced that its wholly-owned subsidiary, **RT Logic**, has been awarded more than \$21 M in multiple government, military and commercial contracts over the past three months, \$11.4 M of which was closed in the fourth quarter of fiscal year 2010. Under the terms of the contracts, RT Logic will provide its proven commercial-based Telemetrix® signal processing systems that are currently used by greater than 85 percent of US space missions.

TriQuint Semiconductor, an RF products manufacturer and foundry services provider, announced that it has been awarded a Defense Production Act Title III gallium nitride (GaN) manufacturing development contract by the US Air Force Research Laboratory (AFRL). The overall goal of the contract is to increase yield, lower costs and improve time-to-market cycles for defense and commercial GaN integrated circuits. The contract was awarded based on TriQuint's success and experience developing new gallium nitride technologies and products.

Auriga Microwave recently secured two contracts with Department of Defense prime contractors. The work product from the two contracts will be derived from Auriga's ongoing successful efforts within the Small Business Innovative Research (SBIR) program.

Demonstrating its key role in helping drive the most advanced 3G and 4G mobile devices, **ANADIGICS Inc.** announced that its power amplifiers have been selected by **Samsung** for their highly anticipated GALAXY Tab product. ANADIGICS' AWC6323 power amplifier (PA) is used in the Samsung GALAXY Tab offered by Sprint and Verizon Wireless in the United States, and ANADIGICS' AWU6601 PA powers the Samsung GALAXY Tab in the Korean market. Both PAs are part of the ANADIGICS High-Efficiency-at-Low-Power (HELP™) portfolio of products that enhance the performance and efficiency of 3G devices.

Applied Radar Inc. recently delivered a 64-Channel Analog RF Receiver Unit (ARRU-64™) to the US Air Force Research Laboratory (AFRL) at Wright-Patterson

AFB, OH. The system development was funded through an AFRL Phase-3 Small Business Innovative Research (SBIR) contract managed by AFRL at Hanscom AFB, MA, and the hardware prototype was purchased by the Air Force through a separate contract from MacAulay-Brown Inc. (MacB) in Dayton, OH.

PERSONNEL

SkyCross announced it has appointed **Ben Naskar**, a wireless industry veteran, to the position of CEO and Chairman of the Board of Directors. Naskar succeeds outgoing Chairman and Acting CEO, Dennis McKenna, who had previously announced his plan to retire at the end of 2010. Naskar has more than 20 years of experience in the wireless semiconductor industry. Prior to joining SkyCross, he was a Corporate Officer, Vice President and General Manager of the Wireless Networking Business Unit at Atheros Communications. In this position, Naskar grew business unit revenue by 200 percent over three years, gaining market share in all product segments. Previously, Naskar served as Vice President and General Manager of the Communications Group at PMC-Sierra.

Aeroflex/Inmet has announced that **Mark Burton** joined its sales team as a Regional Manager of Business Development. Burton had served as Director of Business Development for MCE Technologies prior to its being purchased by Aeroflex. He has also served in various sales, marketing and operations roles at Allan Industries, JFW, Broadwave and Trilithic. He can be reached at (734) 792-9608 or by e-mail at: mark.burton@aeroflex.com.

REP APPOINTMENTS

Paciwave Inc., a supplier of microwave solid-state switches, attenuators, DLVAs and custom integrated microwave assemblies, announced the expansion of its network of regional sales representatives with the following new representative appointments: **Medeos SRL** (+39 02 458 62160), located in the greater Milano area, will be representing the company in Italy. **Versys SARL** (+33 1 69 59 1653), located in the greater Paris area, will be representing the company in France.

Valpey Fisher Corp. announced the addition of **GIGACOMP** to the Valpey Fisher global sales network as its authorized sales representative for all Valpey Fisher Corp. product lines in Germany, Austria, Switzerland and Eastern Europe. The cooperation between Valpey Fisher and GIGACOMP will create greater local presence for Valpey Fisher to introduce its new RF/microwave products in Europe.

America II Electronics Inc., an independent distributor of semiconductors and passive components, has finalized a global authorized distribution agreement with **Aviel Electronics**, a division of RF Industries. Through this agreement, America II strengthens its product portfolio and further demonstrates a commitment to its customers.

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from **$29.95** ea. (1-49)

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Type-N to SMA
DC-18 GHz $22.95 ea.

SMA to SMA

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DC-2 GHz $3.95 ea.

Type-N to Type-N
DC-6 GHz $9.95 ea.

MODELS (Add Prefix BW-)

2 W SMA	5 W SMA	5 W Type-N	Attenuation (dB)	
$29.95	$44.95	$54.95	Nominal	Accuracy*
S1W2	S1W5	N1W5	1	±0.40
S2W2	S2W5	N2W5	2	±0.40
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

To order Attenuators as RoHS, add + to base model No. *Example: BW-S1W2+*
Adapters available as RoHS, see web site.

HIGHLY INTEGRATED KA-BAND TX FRONT-END MODULE WITH AN 8×8 ANTENNA ARRAY

The design of a highly integrated Ka-band TX front-end module is presented. The integration and packaging techniques, which combine the LTCC front-end module with the LO signal generation board, the IF distribution board and the cooling system are considered in detail. The efficient RF design process of the different functional blocks of the LTCC module (antenna elements including hybrid ring feeds, calibration network, 30.6 GHz LO distribution network, active RF circuits, liquid cooling and DC supply), includes full wave EM simulations. During design, it is necessary to carry out EM simulation of the complete front-end module to check for parasitics and layout errors. The manufacture of the demonstrators in LTCC technology is explained and measurement results are presented. The front-end achieves a scan range of ± 60°, EIRP is approximately 40 dBm and the operating frequency band is 29.5 to 30 GHz. This modular system concept can be applied to large antenna arrays in order to fulfill link budget requirements for satellite communication (in this instance) as well as for other phased-array applications.

Future satellite systems, operating at Ka-band frequencies, will provide high data rates, enabling applications such as in flight entertainment in airliners. In the near future, aircrafts could be equipped with electronically steerable antennas, such as those based on digital beam forming (DBF). Electronically steerable antennas based on DBF offer greater flexibility in beam control and are more mechanically robust than mechanical systems. However, the hardware development effort is greater, due to the increased complexity of the system.

At higher frequencies (such as Ka-band, as considered here), the packaging density is very high, which requires suitable system architectures and technologies to handle such a complex level of integration. The combination of the active RF circuit with the antenna in one module decreases the number of high frequency interconnects and reduces the total size significantly.

TX FRONT-END OVERVIEW

The TX front-end is designed with a modular approach. Each front-end consists of a LTCC module with an 8 × 8 patch antenna ar-

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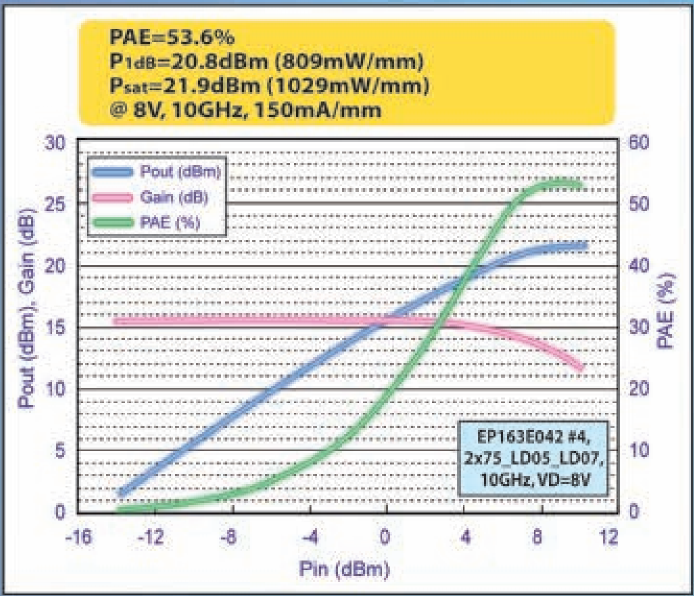
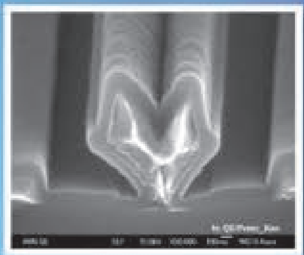
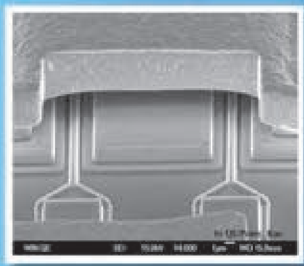
PP25-21 Power Performance







Comparison Table for 0.1µm, 0.15µm, 0.25µm and 0.5µm pHEMT

	PP10	PP15	PP25-21	PP50-11
Vto (V)	-0.9	-1.2	-1.2	-1.4
Idss (mA/mm)	450	500	345	350
Idmax (mA/mm)	720	650	460	480
GM (mS/mm)	750	495	380	310
VDG (V)	9	10	19.2	20
ft (GHz)	130	85	65~72	32
Fmax (GHz)	175	180	160	85
PldB (mW/mm)	533.25 (3.5V)	670 (5V)	809 (8V)	587 (8V)
Psat (mW/mm)	764.3 (3.5V)	820 (5V)	1029 (8V)	851 (8V)
Gain (dB)	14.35	18.1	15.6	15.5
PAE (%)	53.57	55	53.6	53.5
Frequency	29 GHz	10 GHz	10 GHz	10 GHz

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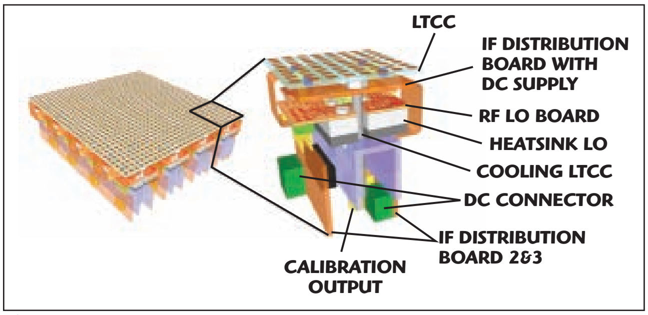


▲ *Fig. 1 3D model of the 64 × 64 element array and the single assembled TX front-end.*

ray and integrated RF electronics, a LO board, IF boards and cooling elements (see ***Figure 1***, right side). Several modules can be combined to form a larger array to fulfill the budget requirements necessary for the specific application. A larger antenna where 16 modules have been combined to form a 64 × 64 element patch antenna array is shown on the left side of Figure 1.

This modular approach results in a design where all RF and DC electronics, including cooling, must fit behind the antenna. The antenna for each patch element is limited by the antenna element spacing, which is half a wavelength. A larger distance between the antenna elements would degrade the antenna performance with respect to the sidelobe level, grating lobe level and scan range. The antenna element area for this Ka-band antenna design is 5 × 5 mm.

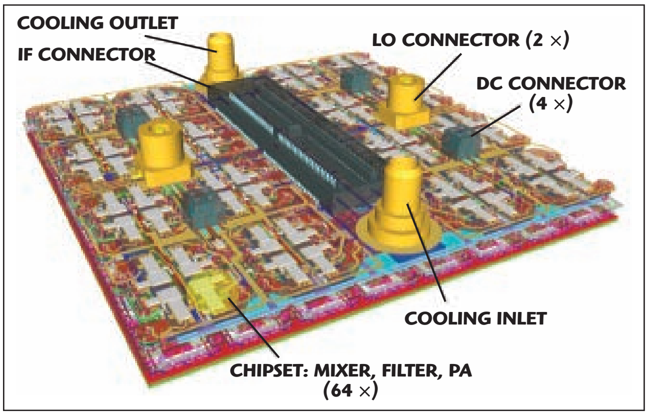
This is a small space, especially for a DBF antenna, as each patch element needs its own chipset consisting of mixer, filter, PA with IF and DC connections to allow for amplitude and phase control at the baseband level. The solution proposed here is a vertical integration of the different functional blocks. Most RF parts have been integrated in a multilayer LTCC module. LTCC technology was chosen due to its flexibility for a multilayer circuit design with a high integration density.

The main parts of the complete TX front-end are the highly integrated LTCC module, the IF distribution boards with DC supply, a board for the 30.6 GHz LO signal creation and the cooling elements. The LO signal is routed with mini SMP connectors from the RF LO board to the LTCC module. An 80 pin connector is used for routing the 64 IF signals, together with several ground connections to the main IF distribution board. Two flex cables connect the IF signals to the second and third IF distribution board from which the IF signals are routed to a rack with the baseband DBF channel boards.

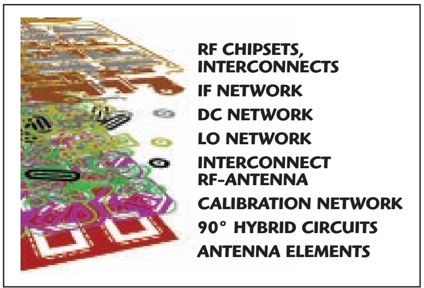
The DC signals are routed with four DC connectors via the IF distribution boards to the DC input connectors. The cooling channels of the LTCC module are connected to an external cooling system by pipes, together with the LO heatsink.

LTCC MODULE DESIGN

The multilayer LTCC module consists of 17 tapes with 18 metallization layers. The following system functionalities of the front-end are integrated:

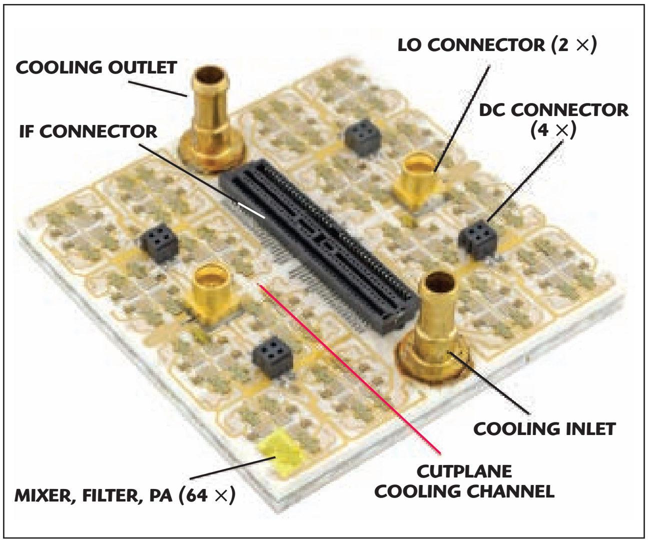


▲ *Fig. 2 3D view from the RF circuit side of the LTCC front-end module.*



▲ *Fig. 3 3D view of the main functional layers from the LTCC module.*

antenna array, including calibration network and hybrid ring feed, RF circuits and cooling system. ***Figure 2*** shows the RF circuit side of the front-end module obtained from the EMPIRE XCcel EM simulation model.



▲ *Fig. 4 Photograph of the LTCC module, including mounted connectors and chipsets.*

The antenna front-end consists of 8 × 8 antenna elements, with separate hybrid ring feed for each element, and an integrated calibration network.[1-3] One edge of the module with the main functional layers is shown in ***Figure 3***. The antenna elements are red and the hybrid ring feed, which is located above the antenna, is purple. Two via holes connect the 0° and 90° output of the hybrid ring feed with the patch antenna (not shown in the figure). The calibra-

tion network (green) collects a small amount of the antenna signal with two probes at each patch.

Wilkinson dividers are used to combine the calibration signal of 16 patches at the calibration receivers (four in total). An interconnection layer (black) in the middle of the LTCC connects the signals of the antenna feed to the output of the PA. This routing layer is necessary as the chipsets of the different antenna patches cannot always be placed directly above the antenna due to the placement of the different connectors (IF connector, LO connectors, DC connectors) on the RF circuit side.

The LO distribution network (yellow) consists of two 1:32 dividers to feed the RF transmitting chip sets, with two additional output ports for the down converters (signal calibration). The DC networks (grey) for gate and drain voltage that supply the PAs are placed between the LO and IF network. One DC network is used to feed 16 PAs. A symmetrical DC routing for each quarter of the module is necessary to ensure a stable operation of the PAs. The two IF networks (brown) connect all 64 mixers to the central IF connector.

The inlet of the cooling system (yellow) and the cooling channels (blue) are shown in Figure 2. Beneath the RF chipsets, inner cavities in the LTCC are used to form a pipework for the cooling system. The RF transmitting chip sets (grey) comprise one amplifier, filter and one mixer (up-conversion) per antenna element. These are located on the RF circuit side of the LTCC module, as shown in Figure 2. Four additional mixers (down conversion) are needed for calibration purposes.

All the different parts of the LTCC TX front-end have been designed and analyzed using the EMPIRE XCcel 3D-FDTD field solver. The design flow for this LTCC module started with the design of the patch antenna, the 90° hybrid circuit and the calibration network. Next, the RF chipsets were integrated, together with the connectors on the surface of the LTCC. The LO network and the IF network were designed later. Finally, the antenna and the RF parts were integrated into one LTCC module. It is important to simulate the complete module with a full wave EM simulation tool.

The simulation of the antenna path starts with a microstrip port at the power amplifier. An impedance transformer and a matching circuit at the top of the LTCC matches the integrated 30 Ω 90° hybrid circuit to the 50 Ω output of the power amplifier. The simulation of the 30.6 GHz LO signal starts at the two mini SMP connectors with a coaxial port and ends at the 64 mixers and at the calibration receivers with microstrip ports. This simulation technique includes all parasitic couplings between the different elements. A retuning of the LO network and some antenna paths had to be applied to compensate for these parasitics.

In addition to the RF characterization, the complete module simulation facilitates the checking of layout errors such as shorts or open circuits. This

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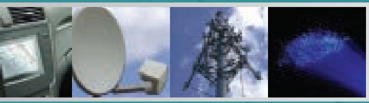

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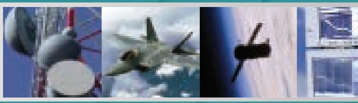

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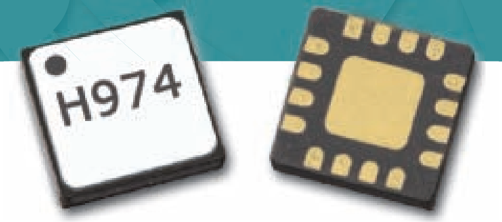
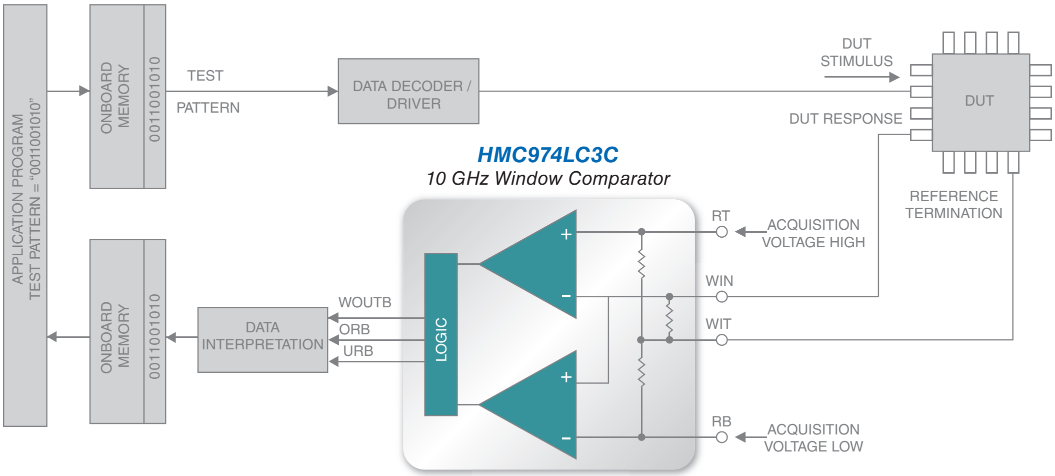


10 GHz Window Comparator

- *Low Random Jitter: < 0.2 ps*
- *Low Overdrive & Slew Rate Dispersion: 20 ps*
- *Low Power Dissipation: 240 mW*
- *Low Propagation Delay: 88 ps*
- *Minimum Pulse Width: 60 ps*

Automatic Test Equipment (ATE)



IN-STOCK HIGH SPEED COMPARATORS

	Analog Input BW (GHz) / Clock Rate (Gpbs)	Function	Deterministic Jitter (ps)	Propagation Delay (ps)	Output Voltage Swing (Vdc)	DC Power Consumption (mW)	Vcco / Vterm [1] Power Supply (Vdc)	ECCN Code	Part Number
	10 / 20	Clocked Comparator - RSPECL	<3	120	0.4	150	+3.3 / +1.3	3A001.a.11.b	**HMC874LC3C**
	10 / 20	Clocked Comparator - RSCML	<3	120	0.4	130	0 / 0	3A001.a.11.b	**HMC875LC3C**
	10 / 20	Clocked Comparator - RSECL	<3	120	0.4	150	0 / -2.0	3A001.a.11.b	**HMC876LC3C**
	10 / [2]	Latched Comparator - RSPECL	2	85	0.4	140	+3.3 / +1.3	3A001.a.11.b	**HMC674LC3C**
NEW!	10 / [2]	Latched Comparator-RSPECL	2	85	0.4	140	+3.3 / 3.0	3A001.a.11.b	**HMC674LP3E**
	10 / [2]	Latched Comparator - RSCML	2	100	0.4	100	0 / 0	3A001.a.11.b	**HMC675LC3C**
NEW!	10 / [2]	Latched Comparator-RSCML	2	100	0.4	100	0 / 0	3A001.a.11.b	**HMC675LP3E**
	10 / [2]	Latched Comparator - RSECL	2	100	0.35	120	0 / -2.0	3A001.a.11.b	**HMC676LC3C**
NEW!	10 / [2]	Latched Comparator-RSECL	2	100	0.35	120	0 / -2.0	3A001.a.11.b	**HMC676LP3E**
	10 / -	Window Comparator	2	88	0.4	240	+2 / 0	3A001.a.11.b	**HMC974LC3C**

[1] Vee = -3.0V & Vcci = +3.3V. [2] These products are pin-for-pin compatible.

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simulation technique ensures a short turnover from design to manufacturing even for such a complex design, with more than 40,000 objects. The simulation of the complete LTCC module needs just approximately 16 GB memory and a simulation time below four hours on a PC cluster of seven standard Intel Core i7 920 PCs. A single dual Xeon 5580 workstation needs about nine hours for the simulation.

LTCC MODULE MANUFACTURING AND ASSEMBLY

The complete LTCC module was realized through 17 tapes of Ferro A6M, which was chosen due to its low loss (tan δ = 0.002) and low permittivity (ε_r = 5.8), compared to other LTCC materials.

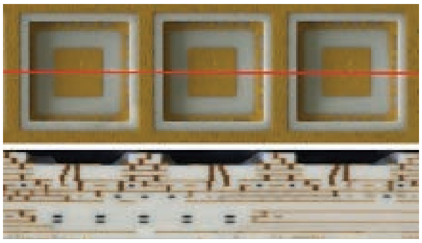
The first tape at the RF circuit side has a fired thickness of 96 µm to enable a higher integration density, while using 50 Ω microstrip lines on the surface. All other tapes have a thickness of 190 µm. Gold paste was used for all internal metallization, vias and at the outer layers, where no soldering of connectors is necessary. A solderable paste (Pt, Pd, Au) was used in the area where the DC, LO and IF connector as well as the cooling inlet and outlet have to be soldered. No post firing process was applied.

General design rules are a fired minimal line width of 100 µm and a minimal line spacing of 100 µm. The fired via diameter is 170 µm. Cavities are used on both sides as well as inside the LTCC. A sacrificial material was used for the inner cavities for the lamination and burn out process to guarantee a good shape of the inner cavities (cooling channels).

A photograph of the RF circuit side from the first prototype of the LTCC module is shown in ***Figure 4***. The x-y direction shrinkage of the LTCC module during the firing process was very stable and varied only between 15.9 and 16.2 percent for 10 different tiles.

To analyze manufacturing accuracies, including for the inner layers, one tile was cut into several slices. A cross-section through a cooling channel, located directly beneath the RF chipsets, is shown in ***Figure 5***. It is clear that the thermal via holes, which are located directly beneath the amplifiers, allow for good thermal conduction between the amplifiers and cooling channel. The cooling channel is two layers high (380 µm), except in the area where transversal tape connections were necessary during production.

▲ *Fig. 5 Cross cut through the cooling channels of the LTCC module.*



▲ *Fig. 6 Cross cut through antenna feed and cavity.*

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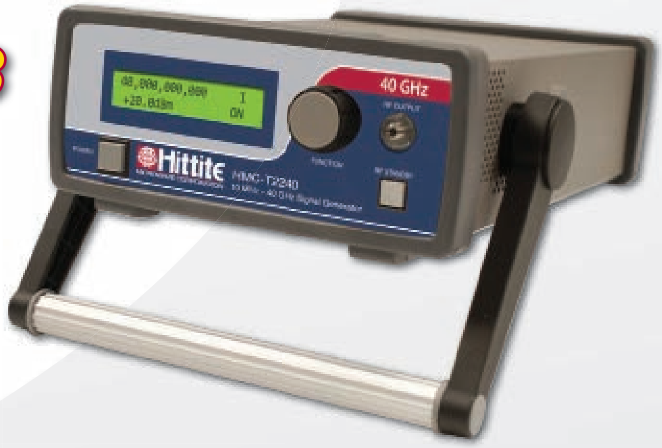

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The input to the cooling channel is at the right side at the junction to the main channel. A cross-section of the antenna elements is shown in ***Figure 6***. The antenna cavities, shielded by via fences, can clearly be recognized, as well as the antenna via feeds and shorting vias in the middle of the antenna patch elements. The shorting via in the center of the patch enhances the polarization purity and the placement of the patches in the cavities reduces the coupling in between the patches. There is a good alignment between the different tapes (better than 50 µm).

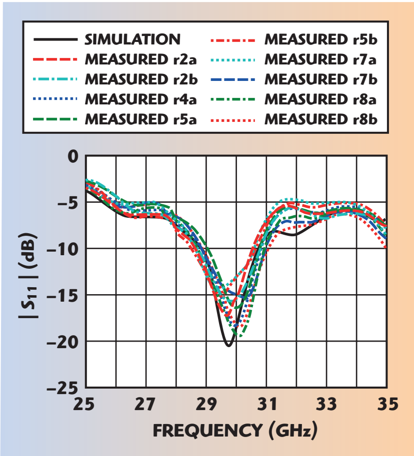
The manufacturing of inner and outer cavities in LTCC is difficult as the high lamination pressure (3,000 psi) often causes deformation. To overcome this problem a sacrificial material is placed inside the cavities. This material is completely removed automatically along with the organic contents of the LTCC tape in the burn-out-phase (350°C … 600°C), leaving accurately shaped cavities behind.

After the manufacture of the LTCC tile and initial test measurements were taken, the IF, DC and LO connectors were soldered, and all the 64 transmitting channels of the module were equipped with the RF chipsets. The RF chipsets consist of a mixer (Hittite HMC 329), an IF filter (specific design) and a PA (Avago AMMC 6232, output P_{1dB} = 20 dBm, small-signal gain = 27 dB, 18 to 32 GHz). These chipset components were mounted to the LTCC with conductive glue.

MEASUREMENTS

The interface between the PA output and the LTCC was designed in a way that on wafer probe measurements can be done to check the functionality of all 64 antenna elements on the LTCC, before the PA is glued and bonded. For these test measurements, each element is contacted on the microstrip RF interface. A sheet absorber material was used on the antenna side to absorb the radiated fields and prevent a reflection at the metal chuck. ***Figure 7*** shows the measurement and simulation results of the return loss at this microstrip RF interface.

One element was singled out and the variation on one module and between different modules was investigated. Each antenna element exists twice on one LTCC module as the upper part can be created by rotating the lower part by 180° around the centre of the whole module. It was found that the return loss of the elements is better than 10 dB over the complete



▲ *Fig. 7 Simulated and measured return loss at the microstrip interface.*

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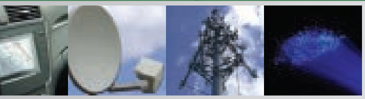

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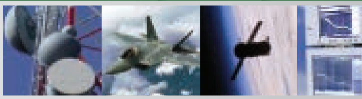

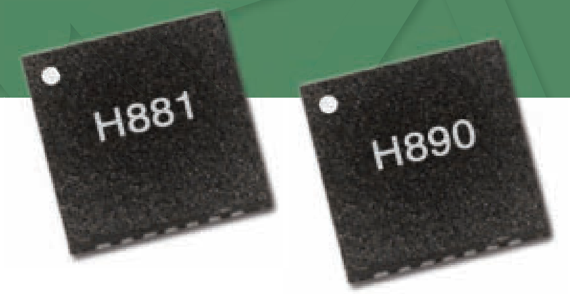

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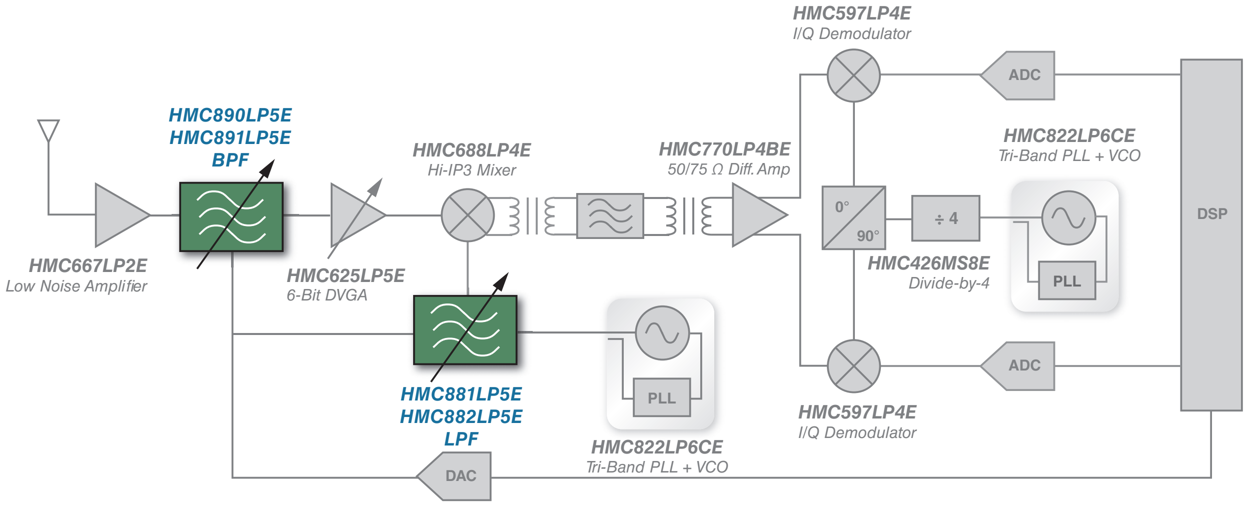

BAND PASS

	Freq. Range (GHz)	Return Loss (dB)	3 dB Bandwidth (%)	Low Side Rejection Frequency (Rej. >20 dB)	High Side Rejection Frequency (Rej. >20 dB)	Tuning Response (ns)	Part Number
	1 - 2	10	11	0.8 x Fcenter	1.2 x Fcenter	200	**HMC890LP5E**
	2 - 3.9	10	9	0.9 x Fcenter	1.15 x Fcenter	200	**HMC891LP5E**
	4 - 7.7	15	9	0.9 x Fcenter	1.13 x Fcenter	200	**HMC892LP5E**
NEW!	9 - 19	9.5	18	0.81 x Fcenter	1.17 x Fcenter	200	**HMC897LP4E**

LOW PASS

Freq. Range (GHz)	Return Loss (dB)	Cutoff Frequency Range (GHz)	Stopband Frequency (Rej. >20 dB)	Tuning Response (ns)	Part Number
DC - 4.0	10	2.2 - 4.0	1.25 x Fcutoff	150	**HMC881LP5E**
DC - 7.6	10	4.5 - 7.6	1.23 x Fcutoff	150	**HMC882LP5E**

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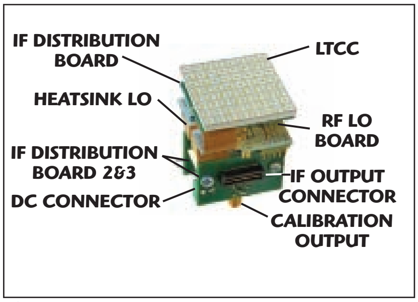
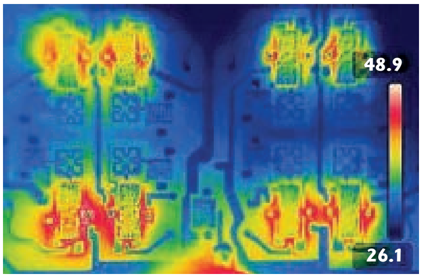
operating frequency band (29.5 to 30 GHz). The agreement between the different curves is excellent and shows good production accuracy. The small discrepancies to the simulation results can be explained because of the deviations in the material parameters and in LTCC shrinkage tolerances. The prototype of the assembled TX front-end module is shown in ***Figure 8***. This front-end module contains the complete assembled and tested LTCC module, the RF- and LO-boards and the cooling system.

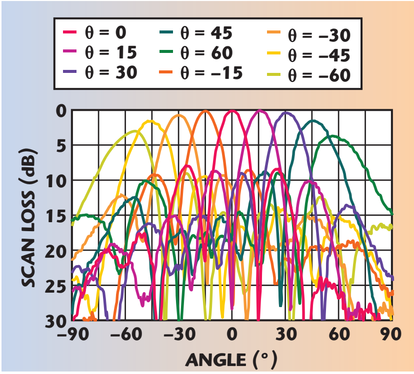
The cooling system of the LTCC module was tested before calibration. DC gate and drain voltage were applied to all PAs after activating the cooling system. Excellent temperature behavior was observed by surface temperature measurement with an infrared camera (see ***Figure 9***). The surface temperature on the PA chips and in the surrounding area stayed below 50°C. Thermal via holes connecting the bottom of the PA chips directly with the cooling channel reduce the PA temperature even more than the temperature in the surrounding area. The large margin between the currently measured PA temperature (< 50°C) and the maximum operating temperature of the PA (~ 150°C) could facilitate a change from a liquid cooling fluid to air.



▲ *Fig. 8 Assembled TX front-end module.*



▲ *Fig. 9 Surface temperature of the LTCC module with active PRS.*



▲ *Fig. 10 Measured co-polar far-field pattern.*

The far-field behavior of the steered 8 × 8 antenna array was determined using an active measurement setup. The antenna was connected with the baseband system to a PC with graphical user interface for amplitude and phase control at the baseband level. All elements can be digitally controlled (DBF) in amplitude and phase. Thus, the 8 × 8 antenna array can be set to different scanning directions, of which the far-field patterns can then be recorded.

Figure 10 shows the measurement

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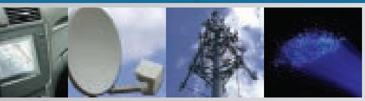

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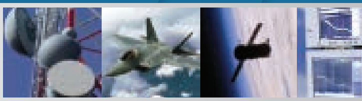
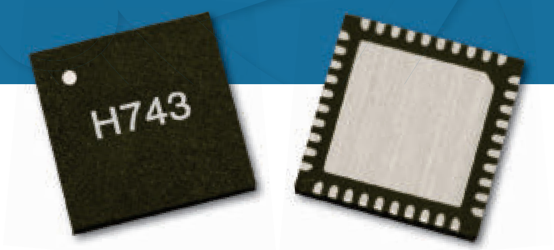


HMC743LP6CE Dual 6-Bit Digital VGA, Serial Control, DC - 4.0 GHz



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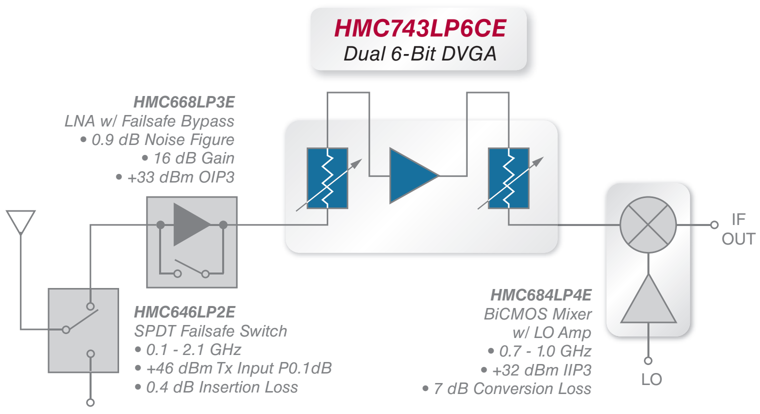

Cellular/3G Front-End Solution

IN-STOCK VARIABLE GAIN AMPLIFIERS - ANALOG & DIGITAL

	Frequency (GHz)	Function	Gain Control Range (dB)	NF * (dB)	OIP3 (dBm)	P1dB (dBm)	Bias Supply	Part Number
NEW!	0.5 - 6.0	Analog VGA	-35 to 15	7.5	28	21	+5V @ 90mA	HMC972LP5E
	2.3 - 2.5	Analog VGA	-9 to +21	2.5	7	3	+3V @ 9mA	HMC287MS8E
	6 - 17	Analog VGA	+1 to +23	5	30	22	+5V @ 170mA	HMC694
	6 - 17	Analog VGA	+1 to +23	6	30	22	+5V @ 175mA	HMC694LP4E
	0.03 - 0.4	5-Bit Digital, Differential Outputs	-4 to +19	5	40	25	+5V @ 250mA	HMC680LP4E
	0.05 - 0.8	5-Bit Digital, Serial & Parallel Control	-8 to +15	5	35	18	+5V @ 65mA	HMC628LP4E
NEW!	0.7 - 2.7	5-Bit Digital, Serial Control	+1 to +32.5	4.4	45	25	+5V @ 218mA	HMC926LP5E
	DC - 1	6-Bit Digital, Serial & Parallel Control	-11.5 to +20	4.3	36	20	+5V @ 90mA	HMC627LP5E
	DC - 1	6-Bit Digital, Parallel Control	+8.5 to +40	4	36	20	+5V @ 176mA	HMC626LP5E
	DC - 1	6-Bit Digital, Serial Control	+13.5 to +45	2.7	36	20	+5V @ 176mA	HMC681LP5E
	DC - 6	6-Bit Digital, Serial & Parallel Control	-13.5 to +18	6	33	19	+5V @ 88mA	HMC625LP5E
	0.07 - 4.0	6-Bit Digital, Serial & Parallel Control	-19.5 to +12	4	39	21.5	+5V @ 150mA	HMC742LP5E
	0.7 - 1.2	6-Bit Digital, Serial & Parallel Control	-2.9 to +29	0.8	38	21	+5V @ 236mA	HMC707LP5E
	1.7 - 2.2	6-Bit Digital, Serial & Parallel Control	-2.9 to +29	1.0	37	21	+5V @ 252mA	HMC708LP5E
	DC - 4	Dual 6-Bit Digital, Serial Control	-45 to +18	6	33	18	+5V @ 82mA	HMC743LP6CE

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results for the right-hand circular-polarization (RHCP), that is the co-polar component for different scanning angles without any amplitude tapering. The scanning behavior is very good and symmetric in each direction. The maximum scanning loss appears at ±60° and is only approximately 3.5 dB. The side lobe level is below -8 dB for all scanning angles, which corresponds well with the theoretical values for uniform amplitude assignment.

CONCLUSION

A highly integrated TX front-end module design, with an integrated 8 × 8 array antenna module, has been presented. The combination of the RF circuit on the one side of the LTCC module and the antenna on the other side saves space and reduces the number of high frequency interconnects compared to a solution with separate modules for all RF circuits and the antenna.

Due to the compact layout of the antenna and the corresponding RF circuitry on the back of the antenna, it is possible to use the 8 × 8 antenna as a base block for larger antenna arrays. The measurement results show a very high reproducibility in the LTCC manufacturing process. The digital control for all elements in amplitude and phase enables scanning angles up to ± 60°.

ACKNOWLEDGMENTS

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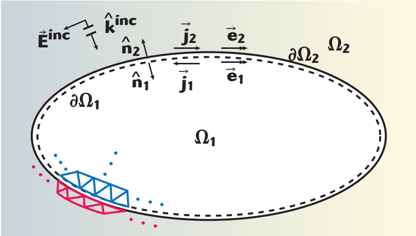
Hybrid Finite Element: Boundary Integral Technique for Efficient Simulation of Radiation and Scattering

The finite element method (FEM) has been widely adopted as an analysis and design tool in many electrical engineering disciplines such as antennas, microwave and signal integrity. An FEM solver offers several important advantages over other numerical methods, including method of moments (MoM) or finite difference time domain (FDTD). These advantages include: 1) the ability to handle complex heterogeneous and anisotropic materials; 2) accurate representation of complicated geometries via tetrahedral elements; 3) accuracy through use of higher order basis functions; and 4) the ability to model with a large variety of port and incident wave excitations. With these capabilities, FEM is able to model waveguide structures with a great degree of accuracy.

However, for unbounded exterior problems, such as an antenna radiating in free space, FEM solvers require truncation of an infinite domain to a finite domain through prescribing radiating boundary conditions (RBC) on artificial truncation surfaces. Two widely used RBCs are the first-order absorbing boundary condition (ABC)[1] and the perfectly matched layer (PML),[2] which typically offers the best accuracy. Both techniques preserve the sparse nature of the FEM system matrix, but are only applicable on convex radiation surfaces. Both are approximate methods with resulting accuracy issues, namely spurious non-physical reflections from the radiation surfaces. This problem can be minimized with the RBC being placed further away from the radiating structure resulting in negligible reflection.

On the other hand, integral equation (IE) methods, such as MoM, are preferred for modeling geometries residing in a homogenous bounded or unbounded medium. Its analytic kernel, the Green's function, takes into account Sommerfeld's radiation condition at infinity. Thus, for multiple disjoint homogenous structures separated in distance, an IE solver provides a much better alternative, both in terms of memory and CPU time, since it does not require explicit modeling of the air regions between targets.

John Silvestro, Kezhong Zhao and Arien Sligar
ANSYS Inc., Canonsburg, PA



▲ *Fig. 1 Domain decomposition of problem domain into FEM and IE domains.*

Hybridization of FEM and IE solvers was accomplished as far back as 1990 by Yuan.[3] This formulation is now commonly known as the hybrid finite element and boundary integral method (FEBI), where the boundary integral (BI), a MoM solution for Sommerfeld's radiation condition, is used as a truncation boundary for the FEM solution. By doing so, an exact theoretical treatment of the far field radiation condition is satisfied. From this a number of interesting features arise, such as radiation surfaces of arbitrary, closely spaced conformal shapes.

In this article, a novel FEBI solver, now available in HFSS from ANSYS Inc., will be presented. The solver is inspired by recent advances in domain decomposition methods. In the present FEBI formulation, an infinite unknown domain is partitioned into two non-overlapping domains: one bounded FEM domain and one unbounded homogenous exterior region. The coupling of these two domains is taken into account through an appropriate boundary condition at the interface.

DOMAIN DECOMPOSITION-BASED FEBI SOLVER

The FEBI solver begins by partitioning the original problem domain Ω into two non-overlapping sub-domains Ω_1 and Ω_2, as shown in ***Figure 1***.

$$\Omega = \bigcap_{i=1,2} \Omega i, \Omega_1 \bigcap \Omega_2 = \varnothing \qquad (1)$$

The common interface between Ω_1 and Ω_2 is denoted as $\partial\Omega_1$ in the FEM domain and $\partial\Omega_2$ in the IE domain. This distinction is necessary because the present formulation allows non-conformal coupling between two domains; namely, meshing, basis function and basis order, matrix assembling and solution process of each domain can be treated independently. The ability to handle different basis orders in a modular fashion for each domain is of vital importance for a robust FEBI solver, because higher order IE solvers are still on-going research topics.

Based on domain decomposition, the final system matrix can be written as

$$\begin{bmatrix} A_{FE} & C \\ C^T & A_{BI} \end{bmatrix} \begin{bmatrix} x_{FE} \\ x_{BI} \end{bmatrix} = \begin{bmatrix} y_{FE} \\ y_{BI} \end{bmatrix} \qquad (2)$$

where A_{FE} and A_{BI} represent the system matrices of FEM and BI domains, respectively. C is the coupling matrix between the two domains. The coupling is done only through electric and magnetic currents at the interface; thus, it is very sparse. The solution of Equation 2 is accomplished iteratively via splitting

$$\begin{bmatrix} A_{FE} & \\ & A_{BI} \end{bmatrix} \begin{bmatrix} x_{FE} \\ x_{BI} \end{bmatrix}^{(n)} = \begin{bmatrix} y_{FE} \\ y_{BI} \end{bmatrix} - \begin{bmatrix} & C \\ C^T & \end{bmatrix} \begin{bmatrix} x_{FE} \\ x_{BI} \end{bmatrix}^{(n-1)} \qquad (3)$$

leading to

$$A_{FE} x_{FE}^{(n)} = y_{FE} - C x_{BI}^{(n-1)}$$
$$A_{BI} x_{BI}^{(n)} = y_{BI} - C^T x_{FE}^{(n-1)} \qquad (4)$$

The benefits of using a domain decomposition approach are apparent from Equation 4. The FEM and BI domains are decoupled; thus, parallelization becomes trivial. The preceding description shows that BI can be used as an exact termination condition in FEM; due to the implementation's modularity, state-of-the-art FEM and IE solvers are easily employed.

APPLICATIONS

In this section, two examples of this hybrid method will be used to highlight the advantages of FEBI. As mentioned previously, the first order ABC can be placed on a sufficiently spaced bounding region that is conformal, but may not be concave. On the other hand, PMLs can be placed closer to the model, but are most easily applied to a rectangular bounding region. For the hybrid FEBI technique—since the coupling between the electric and magnetic currents on the boundary are accurately computed—these shape and size restrictions do not apply. Testing of this new boundary has shown that a spacing of $\lambda_0/10$ provides

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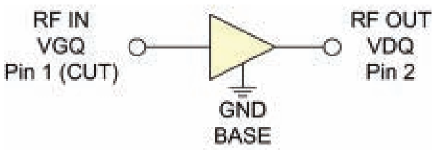

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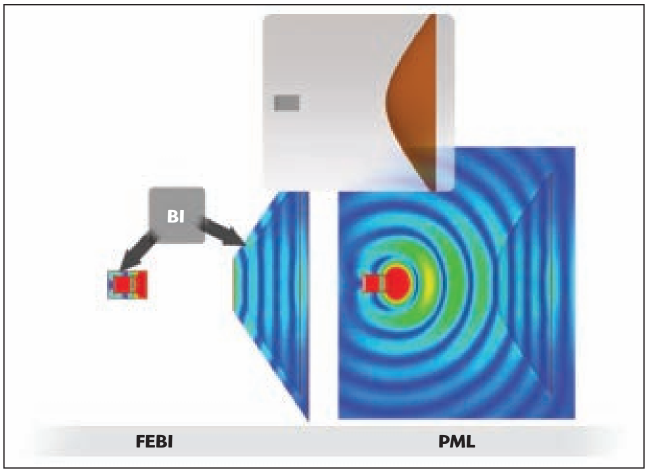
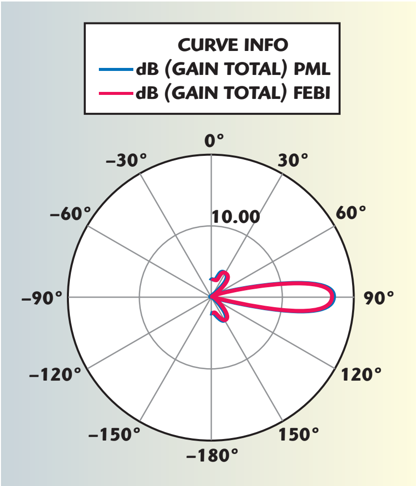


▲ *Fig. 2 Dielectric lens with rectangular feed horn.*



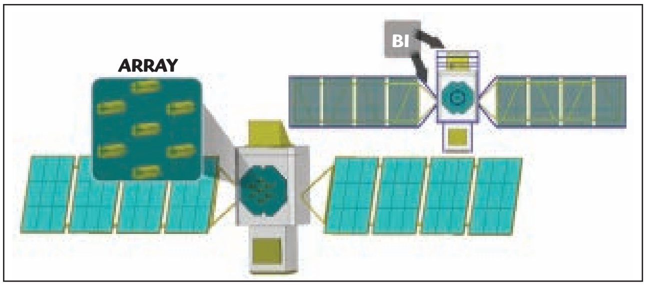
▲ *Fig. 3 Radiation pattern for the lens.*

the optimal compromise between speed and problem size,[5] where λ_0 is the wavelength in free space. In addition, the FEBI boundary can be highly conformal, including concave regions. It is also possible to enclose individual parts of the model in separate domains, each with a BI boundary. By using highly conformal and separate air regions, one can significantly reduce the size of the finite element problem region, resulting in a highly efficient simulation. To illustrate this, let us consider two examples: one using separate volumes and one utilizing a highly conformal boundary surface.

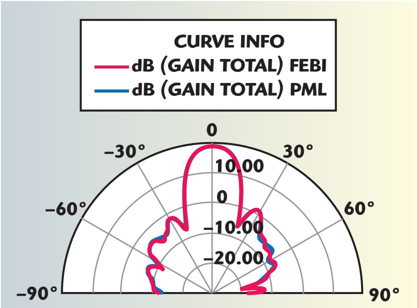
For the first example, the textbook model of a dielectric lens[6] is considered. The lens and its feed horn are shown in the inset of ***Figure 2***. The lens focuses the fields from the source antenna in the forward direction. The lens simulated here with a rectangular waveguide as a feed has an ε_r = 2.56 and a front face with a diameter of $4.4\lambda_0$. A hybrid FEBI was used to model this system using separate air regions with a rectangular air region placed around the feed horn and a conical air volume around the lens. A BI boundary was applied to the bounding surface of both volumes.

For comparison, this antenna system was also modeled using PMLs, where the surrounding air region is a larger rectangular air box that encloses the entire model with sufficient spacing to ensure an accurate response. Using the smaller air volumes in the FEBI model reduced the memory usage by a factor of 10, when compared to the PML simulation. Shade plots of the computed electric fields from the two simulations are shown in the figure. As illustrated, despite using smaller separate air volumes in the FEBI simulation, the fields computed in and around the lens and horn are accurate and agree with fields calculated using the PML. The reflection coefficient (Γ) of the horn is increased when placed near the lens. Both the FEBI and the PML simulations show an identical increase in Γ of 1.8 dB, when compared to the input response for the isolated horn. The pattern in the forward direction for this antenna system computed using both procedures is shown in ***Figure 3***. Once again, the agreement between the FEBI and PML is excellent. The plots in Figures 2 and 3 show the accuracy of the FEBI for characterizing the response of an antenna system, when using separate air volumes.

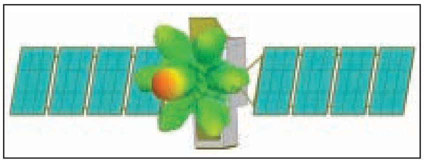
For the second example, an antenna array mounted on a complex platform is considered. This model is shown in ***Figure 4***. It is a seven-element array of helical antennas that are mounted on a satellite platform. The length of the satellite from end to end is 18 feet and the antennas are characterized at 3.5 GHz. This is a large model and so the domain decomposition method (DDM) was also used to split the FEM domain into several



▲ *Fig. 4 Array of helical antennas mounted on a satellite.*



▲ *Fig. 5 Radiation pattern for the antenna array mounted on the satellite.*



▲ *Fig. 6 3D polar plot of radiated fields for the seven-element array with equal excitation.*

smaller domains.[7] This integrated antenna platform system was previously simulated using a standard ABC, with a large enclosing rectangular air box.[5] The volume enclosed in the surrounding air box for that model is ≈ 21000 λ^3; the DDM was used to distribute the solution over 34 domains. The total memory needed for the simulation was 210 GB of RAM.

For the FEBI simulation, a highly conformal air volume was used. This conformal air volume is shown in the inset. This air volume encloses a much reduced 1200λ^3. With this reduced air region and the DDM applied over 12 domains, the simulation required 21 GB of RAM. The memory needed for a FEBI simulation was reduced by an order of magnitude over a solution using a standard RBC. The radiation patterns for all antenna elements excited with equal amplitude and phase from the two simulations are compared in ***Figure 5***. There is an excellent agreement between the two patterns. The full 3D polar pattern for the equally excited antenna array on the satellite simulated using the FEBI is shown in ***Figure 6***. From this example, it can be seen that, by using the FEBI with highly conformal bounding regions, one can simulate large complex antenna systems on a single desktop computer.

CONCLUSION

The hybrid FEBI is a powerful new enhancement to the FEM solver available in HFSS. This new technique gives the design engineer the advantages of an FEM simulation with the efficiency and accuracy of an IE solution for open boundary problems. This procedure is accurate for conformal, concave and/or separate air volumes, allowing users to reduce the size of the FEM solution region resulting in a significant reduction in the solution time and the amount of memory required to solve the problem. ■

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UHF RFID PRINTED DIPOLE ANTENNA WITH CPS MATCHING AND INDUCTIVELY COUPLED FEED

This article presents simulated and measured results of a UHF RFID antenna realized with a dipole matched to a CPS (coplanar stripline) and inductively coupled with a small rectangular loop. Such a design enables achieving and controlling high values of the inductive reactance that is necessary for obtaining good match of the antenna to an Application Specific Integrated Circuit (ASIC) chip. The antenna is characterized by a simple and robust design, which results in low-cost realization.

Radio frequency identification (RFID) is an automatic wireless technology for data transfer developed in the 1970s. This technology has been developing in recent years and has become popular in many service industries, purchasing and distribution logistics, industry, manufacturing companies and material flow systems. It also provides information about people, animals, goods and products in transit, etc. There are several standards that regulate the use of RFID systems depending on the region (ISO, Class 0, Class 1 and Gen 2);[1] thus, for UHF RFID systems, the frequency range is divided into subranges: 866 to 869 MHz (Europe), 902 to 928 MHz (America) and 950 to 956 MHz (Asia).

RFID systems consist of two components: the reader and the transponder (or tag), as shown in **Figure 1**. There are two main classes of RFID systems, depending on the characteristics of the transponder: active or passive. Passive RFID systems, which are more frequent, use the electromagnetic field of the reader for their operation, because the passive transponders do not have their own power supply. Active transponders incorporate a battery, which supplies all or part of the power for the operation.

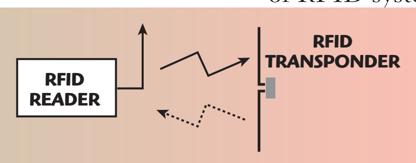

Fig. 1 Reader-transponder-reader link in the passive UHF RFID system.

In digital data transmission between the reader and the transponder, in a full duplex system, the following three types of modulation are mostly used:

- ASK (Amplitude Shift Keying)
- FSK (Frequency Shift Keying)
- PSK (Phase Shift Keying)

Due to its simple demodulation, ASK is commonly used.

The features of any wireless system, including RFID, depend highly on the characteristics of the antenna (a) and the propagation channel (b).[2]

(a) Operating frequency, gain characteristics (maximum gain, radiation pattern, beamwidth, etc.), matching (VSWR or return loss), polarization, sensitivity to nearby objects with different properties.

(b) Path loss, fading.

NENAD POPOVIĆ
AND IVANA RADNOVIĆ
IMTEL Institute, Belgrade, Serbia

Depending on the wireless communication system, some of these characteristics may be more important factors in the design of RFID systems. Thus, operation of passive UHF RFID systems is based on modulation of the reflected RF wave or backscatter from the reader, that differs from modulations in traditional wireless systems, which comprise active transceivers on both sides of the link (802.11, Bluetooth, etc.).

PASSIVE TRANSPONDER: BASIC CHARACTERISTICS

A passive transponder consists of two main parts: the antenna and the application specific integrated circuit. All the energy needed for the operation of the microchip has to be provided from the RF signal received from the antenna. The information necessary for the identification of the object carrying the transponder is written in the ASIC chip. This digital information with precisely defined content and length is stored in an appropriate RAM and written in the ASIC chip memory. Hence, the modulated RF signal emitted from the reader's antenna reaches the transponder's antenna. Part of this energy is used for the transponder's operation by changing its input impedance, according to the modulation information written in the ASIC chip. In the return link from the transponder to the reader, the incoming RF signal is backscattered from the transponder and a proportion of incoming power is returned to the reader's antenna. The processing circuit of the transponder (ASIC) alters its RF impedance and controls the amount of the reflected field. In this case, modulation of the scattered field contains the identification information. The transponder is identified when the reflected field is received and decoded in the reader's unit. The antennas play a crucial role in such a communication system; thus, great attention has to be paid to their design. Some of the main transponder antenna characteristics include:

- They must have dimensions small enough to be attached to the required object
- They must have omnidirectional or hemispherical radiation pattern
- They must provide the maximum possible signal to the ASIC
- They must have a polarization that matches the enquiry signal regardless of the physical orientation of the object
- They must be robust
- They must be inexpensive

TRANSPONDER ANTENNA DESIGN

Two characteristics of the transponder antenna are especially important: the input impedance and the radiation pattern. The input impedance of the antenna has to be matched to the chip impedance; in other words, these two impedances have to be complex-conjugates. Most of the chips have the real part of their impedance approximately a few to several dozens of ohms and a capacitive imaginary part of approximately 100 to 1000 Ω. The antenna must have an impedance with a small real part and with an inductive imaginary part of relatively high value. It should be noted that it is very important to provide a good match between the antenna and the ASIC chip, in order to achieve, as efficiently as possible, the RF energy transmission from the antenna to the chip. The chip in passive RFID systems also uses this energy for its power supply.

The radiation pattern, as already mentioned, has to be omnidirectional. A dipole antenna fulfills this requirement relatively easily; it is usually used in various versions of RFID transponders. Dipoles have a simple structure, so antennas realized with them are not complex and therefore are convenient for in-series production.

For the realization of the antenna, a dipole with CPS matching has been chosen,[3] which enables high values of inductive reactance. By changing its

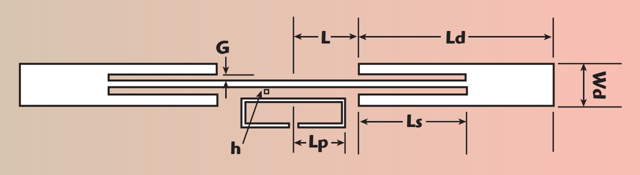

Fig. 2 Layout of the RFID antenna with a dipole with CPS and a rectangular loop.

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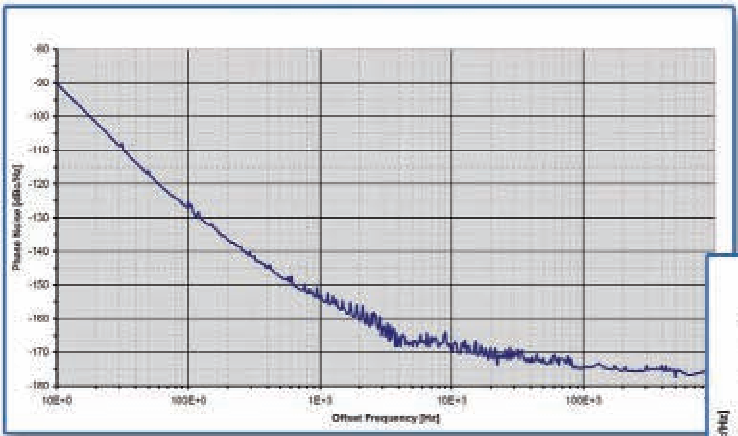
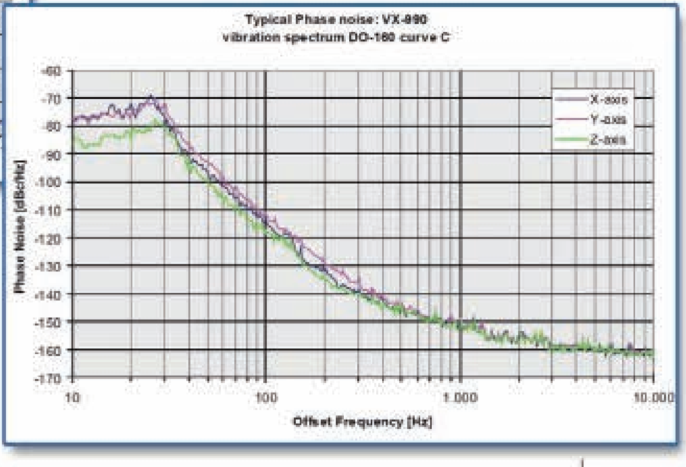


Phase Noise Under Vibration

Frequency: 120 MHz



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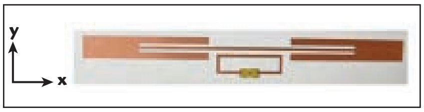
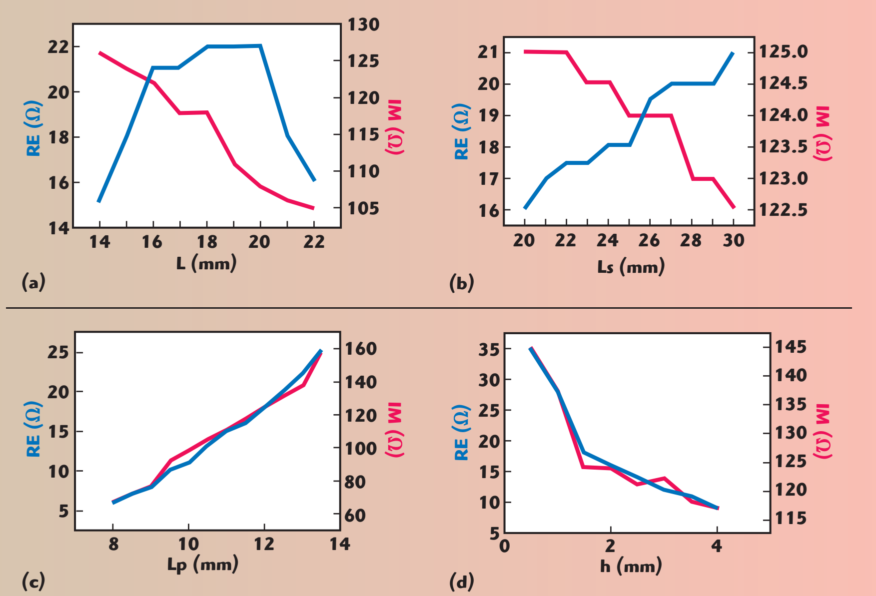


▲ *Fig. 3 Realized RFID antenna with the ASIC chip.*

geometry, that is the length of the dipole arm (Ld) and the length of the matching CPS (Ls), it is easy to control both the real and imaginary part of the dipole's input impedance. In order to achieve greater values of the inductive reactance, one more element—an inductively coupled rectangular loop—was also introduced that enables additional varying and controlling of the antenna's input impedance. ***Figure 2*** shows the layout of the designed antenna. By optimizing the loop's length (Lp) and its distance from the feed line (h), the required value of the input impedance can be easily obtained.



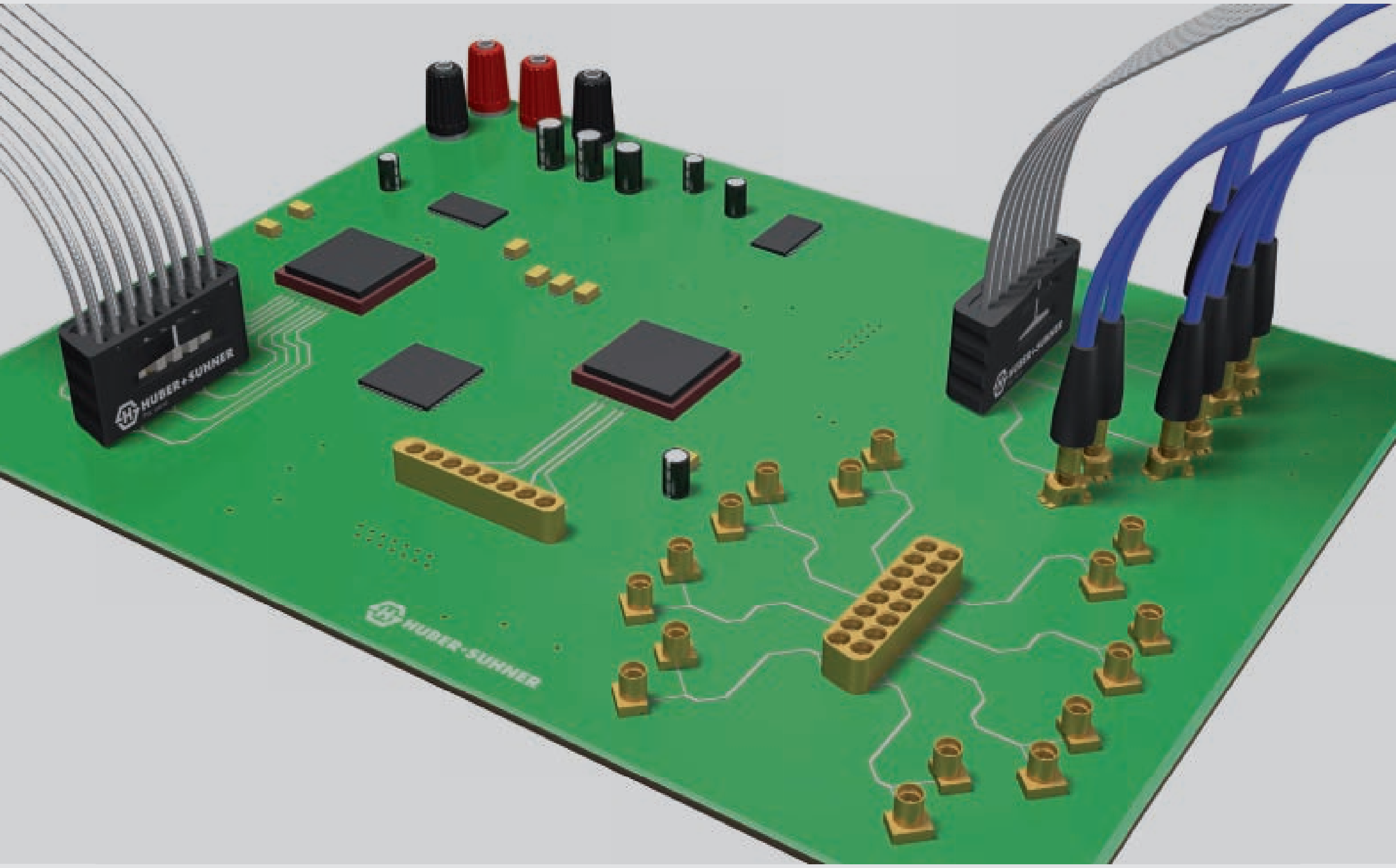
▲ *Fig. 4 Simulated real and imaginary parts of the antenna input impedance for various characteristic dimensions of the antenna.*

REALIZATION OF THE RFID ANTENNA

The RFID antenna is designed for the ASIC chip input impedance of Zc = (20 - j127) Ω at 900 MHz (ALL-9238 from Alien Technology) and a dielectric substrate (Rogers RO4003C) (ε_r = 3.38, h = 0.2 mm). First, only the dipole was analyzed by varying its dimensions, using the program package for electromagnetic simulation. After satisfactory results (high values of inductive reactance and low values of resistance) were obtained, the complete antenna structure, together with an inductively coupled loop, was analyzed. The input antenna impedance attained by simulation is approximately (18 + j124) Ω at 900 MHz for the following antenna dimensions: Ld = 45 mm, Wd = 8 mm, L = 15 mm, Ls = 25 mm, h = 1.5 mm and Lp = 12 mm. The width of the feed line is 1 mm. ***Figure 3*** shows the realized antenna with the ASIC chip.

SIMULATED AND MEASURED RESULTS

The analysis consisted of varying one of the characteristic dimensions at a time, while keeping the others constant, in order to obtain the required impedance value. The diagrams in ***Figure 4*** show the results of the analysis. From the accomplished analysis, one can conclude that the rectangular loop's length (Lp) as well as the distance from the feed line (h) have the most significant effect on the impedance variation. The simulated radiation patterns in the E- and H-planes are shown in ***Figure 5***. The simulated gain of the antenna is 2.45 dBi. Due to the symmetrical input port and the significantly high inductive reactance, the particular problem concerning this antenna type is the input impedance measurement. One solution is to transform the symmetrical input to an asymmetrical one;[4] the other is to use just one half of the antenna placed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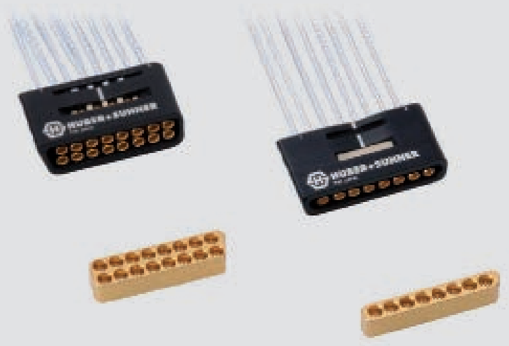
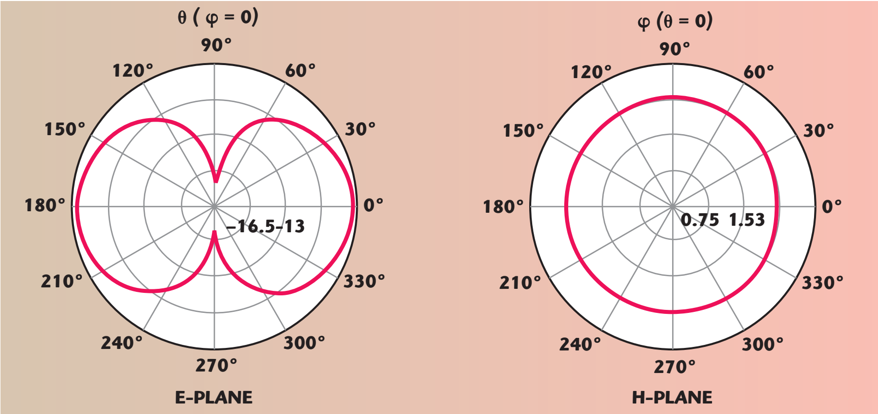
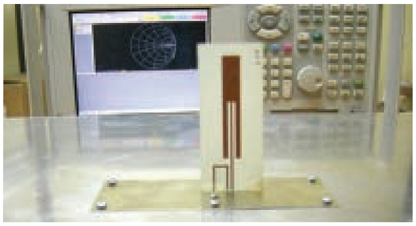




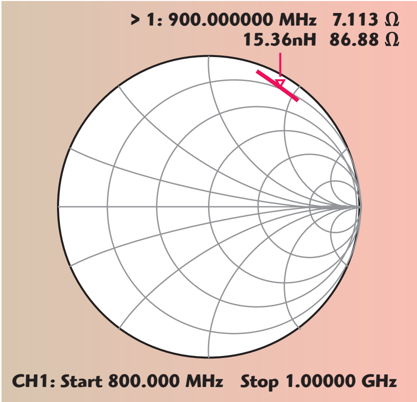
▲ *Fig. 5 Simulated E- and H-plane radiation patterns of the UHF RFID antenna.*



▲ *Fig. 6 Measuring the UHF RFID antenna input impedance using a network analyzer.*

above a conducting grounded plane and thus obtain an asymmetrical input.[5] The latter method is simpler and does not introduce additional losses. In this way, the measured impedance is equal to one half of the whole antenna impedance. The method of measuring one half of the antenna is shown in ***Figure 6***.

The measured input impedance of the realized UHF RFID antenna at 900 MHz using the "one half method" is Za/2 = (10.6+j76.4) Ω (Za = (21.2+j152.8) Ω) and is shown in the Smith chart (see ***Figure 7***). The measured real part of the impedance value deviates from the real part of the ASIC chip input impedance by



▲ *Fig. 7 Diagram of the measured half input impedance of the realized antenna in the range 0.8 to 1.0 GHz.*

1.2 Ω; its imaginary part deviates from the corresponding part of the chip impedance by 25.8 Ω. This indicates good matching that promises low loss of RF energy. Verification of the whole system operation is carried out by measuring the reading distance of the reader-transponder (tag) system. It shows that this distance (measured in an office) is approximately 2 m. The antenna was placed on a cardboard box (object to identify). The overall dimensions of the box were 360 mm × 235 mm × 130 mm.

CONCLUSION

The realized and simulated[6] UHF RFID antenna is characterized by a new and simple design as well as the electrical characteristics that completely satisfy standards of the RFID system. The antenna covers the entire UHF RFID band (Europe, America and Asia). Such simple design implies easy and low-cost manufacturing, especially when realized on inexpensive substrates (PET, PVC) by using screen printing. ■

This work is supported by the Serbian Ministry of Science and Technological Development.

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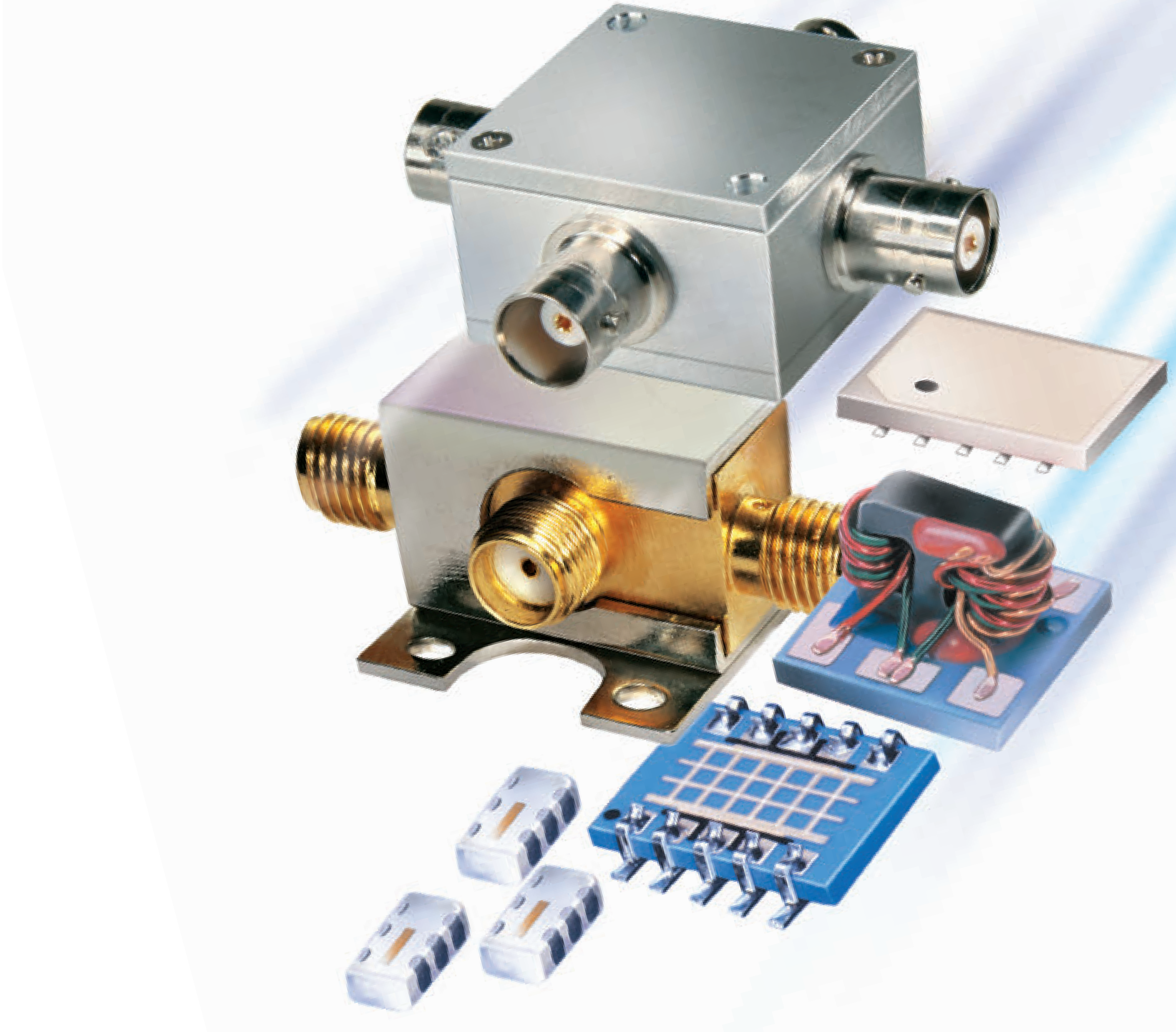

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A MINIATURE LUMPED-ELEMENT LTCC BANDPASS FILTER WITH FINITE TRANSMISSION ZEROS FOR BLUETOOTH APPLICATIONS

A compact, lumped-element bandpass filter with two finite transmission zeros, using a LTCC technique, is proposed for Bluetooth applications. Based on the traditional second-order bandpass filter, a feedback capacitor is added in the middle of the coupled line to obtain two transmission zeros. After describing its working mechanism both graphically and mathematically, commercial software tools were used to accurately model and simulate the filter. To validate the design scheme, the proposed filter was realized using the LTCC technique with the compact size of 3.0 × 1.5 × 0.5 mm. To the best of the authors' knowledge, this is the smallest size for a bandpass filter operating at the center frequency of 2.45 GHz.

Bluetooth wireless technology is a short-range communications technology intended to replace the cables connecting portable and/or fixed devices while maintaining high levels of security. A Bluetooth device, as well as a cell phone, is often carried by people themselves, resulting in a very compact size requirement for the Bluetooth filter. However, continuing reductions in the size of discrete surface-mounted components have diminishing returns because of the incompatibility of the printed circuit board (PCB) technology.

Therefore, one of the important fabrication methods for compact size passive components, particularly for RF passive components, is the low temperature co-fired ceramic (LTCC) technique.[1] Among the various LTCC passive components, people usually pay the most attention to filters.[2-5] In microwave filters, the distributed element approach is often used to obtain lower insertion loss and better stopband performances. However, these designs exhibit comparatively large sizes, due to the fundamental disadvantage of using quarter-wave sections at relatively low frequencies. With the added new design dimension in the z-direction provided by LTCC, lumped-element RF filters have been implemented in stacked structures, which not only provide various coupling mechanisms to achieve better frequency selectivity, but also shrink the size.[6-9]

To obtain a sharper rate of cutoff and without using a higher order of filter, the method of zero transmission is adopted.[7-8] Yeung and

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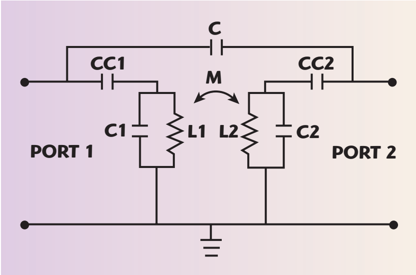
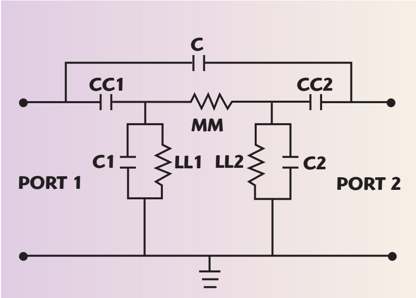
Wu[7] have demonstrated that a filter with zero transmission not only has a better selectivity, but also has nearly the same pass band characteristics as those of traditional second-order coupled-resonator filters. However, good performance is achieved in the stop band; the overall size of the filter is 4.3 × 2.0 × 0.53 mm. Although Tang obtained better performance in the stop band and realized a more compact size[8] (2.8 × 2.6 × 0.6 mm), the two transmission zeros appear on the same side of the pass band, so the characteristics of the other side of the stop band are poor. Recently, two new bandpass filters using third-order topology without transmission zeros have been reported.[9] The new bandpass filters have desirable performance characteristics, but the overall sizes are 5 × 5.4 × 0.8 mm and 5 × 6 × 0.8 mm, respectively.

In this article, the inserted capacitance and inductance are modeled and the theory of transmission zeros is analyzed. A compact LTCC 2.45 GHz (the Bluetooth frequency) lumped-element bandpass filter with two transmission zeros is introduced. A prototype filter of size 3.0 × 1.5 × 0.5 mm (0.02λ × 0.01λ × 0.004λ) has been implemented in a multilayer LTCC substrate for experimental verification. It is believed that this is the minimum size for a bandpass filter operating at the center frequency of 2.45 GHz. The measured results show that the insertion loss is less than 4.8 dB and the return loss is better than 13 dB.



▲ *Fig. 1 Schematic of a two-pole, second-order filter.*



▲ *Fig. 2 Alternative representation of the mutual inductor.*

MODEL

The finite transmission zeros are mainly caused by blocking energy, so serial or parallel LC resonance circuits can be used in order to introduce a pair of finite transmission zeros. A well known two-pole filter schematic is shown in ***Figure 1***.[7] It consists of a second-order coupled resonator bandpass filter with a feedback capacitor. The purpose of the feedback capacitor C is to introduce a pair of finite transmission zeros to the transmission characteristics of the filter. The pass band characteristics will not be impacted by the feedback capacitor C. As shown, there is a mutual coupling M. To simplify the analysis, the circuit is transformed to the one shown in

Figure 2, using the Y-to-Delta transformation. The values of the inductors in the representation configuration are given by[7]

$$\begin{aligned} LL1 &= \frac{(L_1-M)(L_2-M)+(L_1-M)M+(L_2-M)M}{L_2-M} \\ LL2 &= \frac{(L_1-M)(L_2-M)+(L_1-M)M+(L_2-M)M}{L_1-M} \\ MM &= \frac{(L_1-M)(L_2-M)+(L_1-M)M+(L_2-M)M}{M} \end{aligned} \quad (1)$$

where M is the mutual coupling, and L1 and L2 are the lumped inductors of the filter.

SIMULATION AND OPTIMIZATION

According to the above discussion, a bandpass filter with a 2.45 GHz center frequency and two transmission zeros has been designed. The substrate material is a ceramic, with a $\varepsilon_r = 14$ and a $\delta = 0.0015$. Based on the synthesis method for a bandpass filter outlined by Sun, et al.,[6] the normalized parameters of the second-order Chebyshev-type bandpass filter prototype circuit are g0 = 1, g1 = 1.0378, g2 = 0.6745 and g3 = 1.5386. After introducing the frequency, the component values are CC1 = CC2 = 0.85 pF, LL1 = LL2 = 1.64 nH, C1 = C2 = 2.25 pF and MM = 8.79 nH. The value of the feedback capacitor C can be selected depending on the desired locations of the transmission zeros.

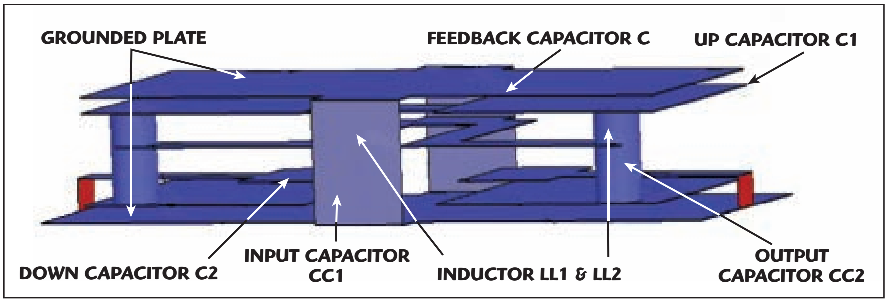
With the multilayer capability of the LTCC technology, the lumped-element model can be readily realized by using parallel plates for the capacitors and a metallic strip for the inductors. The structure of the lumped-element bandpass filter is shown in ***Figure 3***. The up capacitor and down capacitor are a parallel connection, and the inductor is implemented by a single layer spiral inductor. The size of the inductor and the capacitor can be initially obtained from Equations 2 and 3

$$L = \frac{\mu_0 \mu_r A_e}{l_e} \cdot N^2 \quad (2)$$

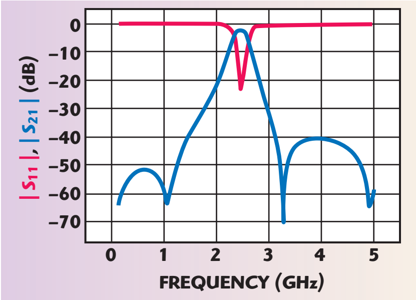
$$C_{eff} = (n-1)\frac{\varepsilon_0 \varepsilon_r S}{d} \quad (3)$$

where C_{eff} is the capacitance of the capacitor, n is the number of layer of the capacitor, ε_r is the relative permittivity of the medium, S is the area of the plate and d is the distance between two adjacent plates.

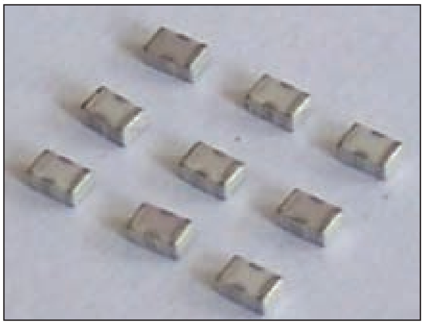
As shown in the figure, there are seven layers in the LTCC structure; the height of every layer is 0.006 mm. The top and the bottom layers are the grounded plates. The second and sixth layers are the parallel capacitors C1 and C2, respectively. The third layer is the feedback capacitor C, using a dumbbell shape. The fourth layer is composed of inductors LL1 and LL2, which are coupled to each other to fulfill the coupling inductor MM. One port is grounded and the other port is connected to C1 and C2 by the through hole. The fifth layer is composed of the input capacitor CC1 and



▲ *Fig. 3 3-D structure of the bandpass filter with two transmission zeros.*



▲ *Fig. 4 Simulated results for the bandpass filter with two transmission zeros.*



▲ *Fig. 5 Photograph of the fabricated filters.*

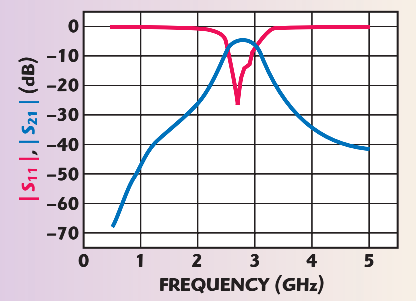
output capacitor CC2.

The final structure was simulated and optimized using the 3-D full-wave electromagnetic (EM) simulation tool Ansoft HFSS. The simulation results are shown in ***Figure 4***. It can be seen that the center frequency is 2.45 GHz, the insertion loss in the pass band is less than 2 dB and the return loss is better than 20 dB. Additionally, there are two transmission zeros at 1.1 and 3.2 GHz, respectively.

FABRICATION AND MEASUREMENTS

The final filter has been designed and built in an LTCC format using Ferro ULF140 with a ε_r = 14 and a δ = 0.0015. Before designing the silk screen, attention should be paid to the shrinkage rate of the ceramic ULF140. The filter has employed a lumped-element envelop 1206 (3.0 × 1.5 × 0.5 mm) and has been fabricated at the LTCC Engineering Center, University of Electronics Science and Technology of China (UESTC). A photograph of the filter is shown in ***Figure 5***.

The measurements were performed by connecting a test fixture provided by the LTCC Engineering Center of UESTC to the two external ports of the filter. The frequency response of the filter was measured using a network analyzer Agilent 8722ES; the measured curves are drawn in ***Figure 6***. As can be seen, the mea-



▲ *Fig. 6 Measured results for the bandpass filter.*

sured insertion loss of the filter is less than 4.8 dB and the return loss is better than 13 dB within the passband. The stopband (lower than 1.8 GHz and higher than 3.6 GHz) rejection is greater than 30 dB. However, the measured center frequency shifted from the simulated 2.45 to 2.69 GHz. It may be due to the ceramic sintering process failing to reach the appropriate temperature, resulting in an undesired dielectric constant. On the other hand, the transmission zeros shown in the simulation do not show up in the measured data. The reason may be that the screen design is based on the average rate of contraction, but the experimental sintering shrinkage rate did not achieve the desired result, so that the capacitance of the feedback capacitor is reduced.

CONCLUSION

By introducing a feedback capacitor, a lumped-element bandpass filter with dual transmission zeros and using LTCC technology is presented. The filter is simulated and optimized with the 3-D electromagnetic code Ansoft HFSS for a center frequency of 2.45 GHz. In order to verify the design, the filter was fabricated using LTCC technology. The test results show that the filter has good transmission characteristics, with a pass band insertion loss less than 4.8 dB and a return loss better than 13 dB. The device has a compact size of 3.0 × 1.5 × 0.5 mm (0.02λ × 0.01λ × 0.004λ). The filter has promising potential to be applied to the increasingly widespread use of Bluetooth devices and other mobile communications equipment. ■

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NEW RF METRICS FOR THE SMARTPHONE-CENTERED WORLD

A decade ago, "cell phones" were all about voice communication, an extension of the home phone for those who needed to be on the go. Global roaming was minimal at best, with multiple communications standards worldwide: GSM, TDMA and CDMA, primarily, with many devices carrying backward compatibility to AMPS. To match these applications, RF power amplifier (PA) performance was all about peak power capability. Performance at 3.4 V was the key metric as it drove output power capability and, as a result, a handful of parameters based on modulations characteristics were evaluated along with the key product differentiator, power added efficiency (PAE). Essentially, suppliers and customers alike utilized "static" measurements and kept evaluations very straightforward.

Fast-forward to today's Smartphone-centered world and one will quickly find that these "static" measurements are not nearly as relevant; they are evaluating more of the exception than the rule. The implication is that these simple metrics are driving incorrect tradeoffs in cellular front-end and PA design. Today's Smartphone-centered world deserves Smartphone-centered front-ends. These front-ends operate in a dynamic world and need new, "dynamic," Smartphone-centered metrics to succeed.

SMARTPHONES = MOBILE DATA

First and foremost, while a Smartphone can simply be described as a new generation of mobile devices, the mobility attribute has expanded dramatically. Rather than simply being an extension of voice communication when someone is away from their home or desk phone, mobile phones are quickly becoming the only phone owned by many individuals. And, with the growing coverage of GSM and W-CDMA networks, mobile now also means global roaming—across multiple countries and multiple mobile operators. Secondarily, while still a tool for voice communications, Smartphones are predominately data-driven devices—whether users are surfing the Internet, downloading the latest video or song, or twittering about their latest favorite restaurant.

The RF implications of these new usage models are quite dramatic. Smartphone users seek the longest operating time between charges, given their heavy data usage during the day, so making the most of a battery's full range of operation is increasingly important. Next, the form factor of these devices has decreased dramatically despite increased semiconductor content. The net result is an

BEN THOMAS AND JACKIE JOHNSON
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extremely compact design that is unable to mask the heat generated by inefficient operation; thus, thermal performance has jumped to the forefront of consideration in new components. The use of DC-DC converters to address these thermal concerns is also on the rise. Third, an understanding of the usage models of the global cellular communication standards indicate a much more dynamic output power model for mobile devices, with peak power being more of the exception than the rule. Combining these factors with global roaming across various network operators' infrastructure deployment strategies creates a need for the RF to be the most efficient for any given power level the network dictates. Last but not least, Smartphones are data devices by design. With the multitude of data modulations driving various linearity and power requirements, dynamic assessments of performance are mandatory to fully evaluate an RF front-end's or a PA's fit for the application.

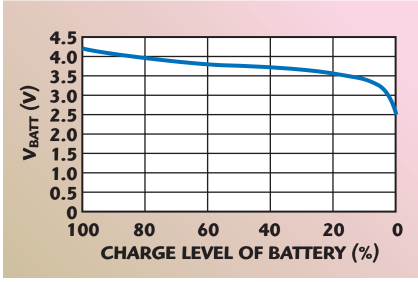
IT IS ALL ABOUT BATTERY CURRENT DRAW THESE DAYS

In the past, efficiency was used as the primary metric for a PA's performance in a cellular application, particularly at peak power and a single voltage, traditionally 3.4 V. In reality, however, a mobile phone's battery does not stay at a constant voltage; in fact, as illustrated in ***Figure 1***, a lithium-ion battery's voltage changes based on the percent charge. The battery voltage typically ranges from around 4.2 to 3 V, depending on the amount of charge available. When one examines the battery discharge curve in detail, data reveals that for over 80 percent of the operating time the battery voltage is above 3.4 V—the first evidence that the traditional measurement point is the exception not the rule.

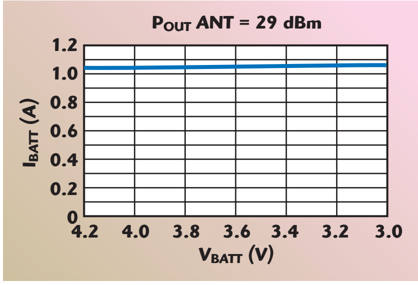
Looking back to the use of efficiency as an indicator of performance, efficiency has been the staple for comparing RF front-ends, although they require a subjective choice of a single voltage point. This metric is convenient to measure and evaluate, but does not represent real-world usage models. For example, the calculation for efficiency can be used to demonstrate the delta in performance between traditional GSM PA solutions that do not incorporate DC-DC converters because these PAs utilize a fixed collector voltage for operation.

$$Eff\% = \frac{\dfrac{10^{\frac{Pout}{10}}}{1000}}{Vcc\ Icc} * 100 \qquad (1)$$

As a result, at a battery voltage of 3.4 V while delivering 31 dBm of power at the PA output, the efficiency is ~35 percent, which is typical for solutions today. By changing the battery voltage to 3.8 V the calculation for efficiency shows a degradation of over 4 percent, which is a result of the energy being dissipated thermally. While this shows a reasonable indication of the potential thermal implications of the solution, efficiency's dependence on battery voltage does not give a good indication of the solution's effect on battery life and the resulting end user's talk-time. Specifying RF front-ends in terms of current consumption (mA) is the only true way to compare solutions as to their impact on talk time since batteries are specified by their capacity in mA/hours. Therefore, a better comparison, which more closely resembles real-world usage models, is to calculate average current consumption across the discharge curve. Additionally, this will take into account the possibility of a solution that utilizes a DC-DC converter to adjust PA collector voltage with output power—a common theme in today's Smartphone RF solutions—and provide a way to better compare the benefits of the two types of implementations.



▲ *Fig. 1 Li Ion battery discharge curve.*



▲ *Fig. 2 Current vs. battery voltage for solutions with no DC-DC converter.*

In terms of measuring current consumption, a PA designer could, in a straightforward fashion, measure current over the operating voltage range. In a traditional GSM PA not connected to a DC-DC converter, we find, intuitively, that current consumption remains constant over the battery voltage range (see ***Figure 2***).

However, in a solution that utilizes a DC-DC converter to supply the PA collector voltage, we find that current consumption varies with battery voltage. Thus, since the battery voltage varies with charge level, we can measure the current consumption relative to the battery charge level (see ***Table 1***).

TABLE I

MEASURED DATA OF RF FRONT-END WITH DC-DC CONVERTER

Charge Level (%)	Vbatt (volts)	Ibatt (amps)	DC Pin
100	4.2	0.600	2.52 W
92.3	4.1	0.614	2.51 W
83.9	4.0	0.628	2.51 W
72.3	3.9	0.643	2.50 W
53.1	3.8	0.659	2.50 W
30.8	3.7	0.675	2.49 W
20.3	3.6	0.693	2.49 W
13.8	3.5	0.712	2.49 W
9.51	3.4	0.733	2.49 W
5.98	3.3	0.754	2.48 W
4.27	3.2	0.778	2.48 W
2.88	3.1	0.802	2.48 W
2.21	3.0	0.829	2.48 W
1.54	2.9	0.857	2.48 W
0	2.5	---	

Next we graph the current consumption over the charge level (see ***Figure 3***.). By taking the polynomial and integrating the curve, it gives us Equation 2

$$\int \text{Ibatt}(L)dL = \frac{P1}{11}L^{11} + \frac{P2}{10}L^{10} + \frac{P3}{9}L^{9} + \frac{P4}{8}L^{8} + \frac{P5}{7}L^{7} + \frac{P6}{6}L^{6} + \frac{P7}{5}L^{5} + \frac{P8}{4}L^{4} + \frac{P9}{3}L^{3} + \frac{P10}{2}L^{2} + P11L \quad (2)$$

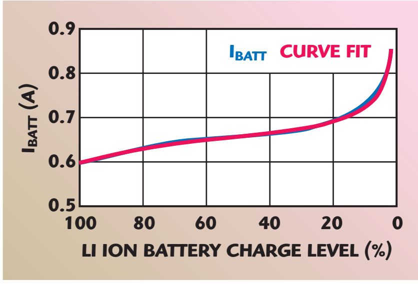
Computing the equations reveals that this solution will give the designer an average current of Ibattavg=0.665A.

Comparing the two GSM PA solutions delivers a calculated, non-subjective measurement of relative performance, along with metrics that are directly and easily correlated to battery life and talk-time. In this case, the solution that utilizes a DC-DC converter can more efficiently utilize current for the given, backed-off power level (ECTEL power of 29 dBm), resulting in ~400 mA less average current consumption. A Smartphone RF architecture that values GSM current consumption at backed-off power levels would quickly see a significant advantage in implementing a DC-DC converter.

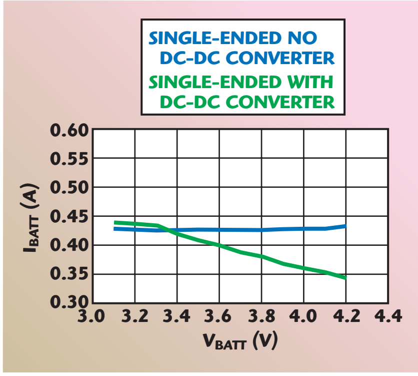
Conversely, if we stayed with a traditional measurement of peak power at 3.4 V, the solution with a DC-DC converter would show much worse current consumption. However, again, this single measurement point does not adequately depict the situation. As shown in ***Figure 4*** (similar to the backed-off power example), when one considers the average current over the battery voltage and weight that given the percentage of time a battery is at the voltages, one can intuitively see that, given normal mobile phone operation, the better performing solution is one that utilizes a DC-DC converter.

THERMAL CONCERNS ARE ON THE RISE

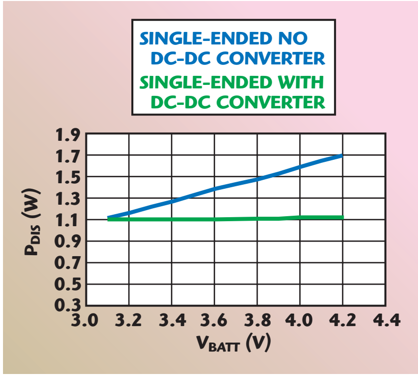
Taking the data from the above example, similar methodologies are used to evaluate the impact of varying current consumption on thermal performance (see ***Figure 5***).



▲ *Fig. 3 Data graphed with a 10th order polynomial curve fit applied.*



▲ *Fig. 4 Current consumption vs. battery voltage.*



▲ *Fig. 5 Power dissipated vs. battery voltage.*

Based on the conservation of power we quickly see that over the majority of the battery discharge curve of a non-DC-DC converter-based solution will dissipate dramatically higher thermal energy. Approximately 1.5 to 2 W of heat being dissipated in the Smartphone is easily noticed by the end user depending on the form factor and thermal properties of the Smartphone. Since W-CDMA is full duplex (meaning the system transmits and receives simultaneously), the PA is powered on and transmitting for the full duration of the data call. GSM, on the other hand, is time-based, resulting in 1/8 duty cycle of the PA up to 4/8 for GPRS multi-slot operation. In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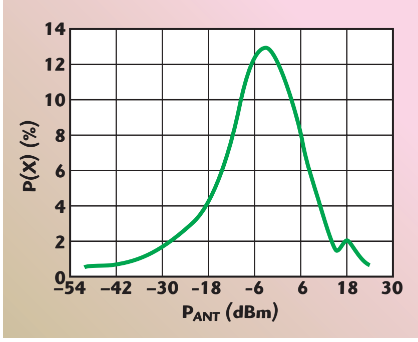
a contrasting case, if the W-CDMA PA consumes 400 mA of current, this is a constant requirement from the battery. In a GSM system, if the PA consumes 1.5 A of current and the duty cycle effect is applied, this would result in less than 200 mA of average current. Examining these two types of systems, it is easy to understand why DC-DC converters have been broadly adopted in full duplex systems—to help minimize this thermal dissipation.

With these examples, it is clear that measuring the thermal impact of a PA solution—no matter the communications standard—is best done by evaluating an average thermal dissipation over intended use range of the battery discharge curve.

MOVING PEOPLE + FIXED INFRASTRUCTURE = VARYING OUTPUT POWER

While this concept of output power varying as a mobile phone moves with its user seems intuitive, still it remains that for the last decade the dominant majority of metrics have been related to peak power levels. The CDG curve developed for CDMA-based mobile operators was the first attempt to more adequately depict what is really happening with a mobile phone's output power during typical operation. GSM Association quickly came up with a similar metric, as the expansion of W-CDMA modulation showed similar attributes, and the DG.09 curve, which estimates the probability density of varying output powers for W-CDMA voice modulation, was created (see ***Figure 6***).



▲ *Fig. 6 DG.09 probability density function.*

Despite the fact that both the CDG and DG.09 curves have been around for a while, there remains a large focus on single power level metrics, which can quickly drive the wrong decision points. For example, let us compare two completely different W-CDMA PA control architectures: a single-ended W-CDMA PA that has three distinct power modes (PA "A"); and a quadrature W-CDMA PA that utilizes continuous analog bias control and collector voltage adjustment coming from a buck DC-DC converter (PA "B"). Often these two types of solutions would be measured at 0 and 24 dBm (peak) output power to see which has the best performance. ***Table 2*** shows that the difference is performance, and, at quick glance, one can see the detriment of using a "static" metric. If 0 dBm or peak current consumption was used, PA "A" might be chosen. If the metric for decision making was DG.09, which is a better representation of W-CDMA voice performance, the decision maker chooses PA "B," while also gaining the benefits of a quadrature PA solution—VSWR tolerance and broadband capability.

SMARTPHONES = DATA

Thus far we have centered the discussion of metrics on voice-centric performance. Smartphones, however, spend the majority of their time in a data mode. With each new Smartphone rollout we are seeing an increase in the number of data modes—basic W-CDMA data, then HSPA and now HSPA+. Each mode carries different performance requirements and demands on the PA solutions. In short, as the data rate goes up, the implication on power output is on the rise in the center point of the output power probability density function (PDF). For example, although little to no formal data has been published, in speaking

TABLE II

CURRENT CONSUMPTION COMPARISON OF TWO W-CDMA ARCHITECTURES

W-CDMA PA Architecture	0 dBm Icc	24 dBm Icc	DG.09 Icc
PA "A"- SE, 3 power-mode	9 mA	420 mA	26 mA
PA "B"- Quadrature, analog bias and collector voltage control	12.5 mA	460 mA	22 mA

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 SA50 $288.00 2.4MM 50GHZ	 SA4014 $142.00 2.92MM 1W 40GHZ	 SA26B $75.00 SMA 27GHZ	 SA18H $30.50 SMA 18 GHZ	 SA6H $20.00 SMA 6GHZ	 SA6Q $29.00 QMA 6GHZ 2W
 SA3011 $12.75 SMA 3GHZ BRASS	 SA4017 $500.00 2.92 40GHZ 5W	 SA3S5W $36.00 SMA 3GHZ 5W	 SA3N10W $70.00 N 3GHZ 10W	 SA18S10W $122.00 SMA 18GHZ 10W	 SA3T $29.00 TNC 3GHZ 2W
 SA18N $47.00 N 18GHZ	 SA3NS $26.00 N 3GHZ	 SA3N5W $40.00 N 3GHZ 5W	 SA18N10W $123.00 N 18GHZ 10W	 SA4N-50 $170.00 N 4GHZ 50W	 SA18N100 $700.00 N 18GHZ 100W

ADAPTERS 0-65 GHZ

 SM3250 $198.00 2.92 M/F 40GHZ	 SM3929 $409.00 1.85-1.85 65GHZ	 SM3985 $135.00 1.85-3.5 34GHZ	 SM8902 $105.00 MINISMP-SMA 26GHZ	 SM4216 $25.00 N-M-SMA 6GHZ	 SM4742 $39.50 SMA-TNC 18GHZ

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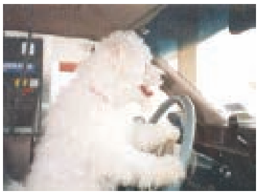

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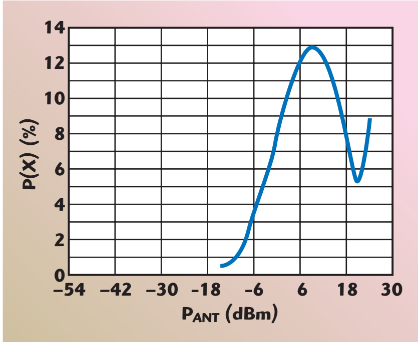
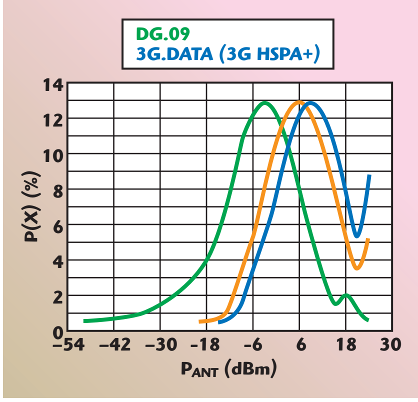


▲ *Fig. 7 3G data probability density function.*

with many customers and cellular platform providers there is general consensus that, on average, where DG.09 is "centered" around 0 dBm, higher order data modulations are centered between 10 to 15 dB higher based on the needs to ensure sufficient data throughput. This requirement is logical as the higher order modulation formats place more symbols in the constellation. As more symbols are packed in the constellation there is less error in phase and amplitude between the symbols resulting in higher bit error rates (BER). This requires the transmit (TX) system to increase power, resulting in higher signal to noise ratio (SNR) at the receiver, thus limiting the BER and error correction. This results in faster data rates. To begin measuring average current consumption with these data rate im-



▲ *Fig. 8 Composite of 3G and 4G PDF curves.*

plications in mind, a 3G data PDF is shown in ***Figure 7*** and ***Table 3*** to measure the dynamic performance of a W-CDMA PA.

Looking to the future and 4G LTE adoption, it would be prudent not to make the same mistake again by assuming "static" measurement points as history tells us that this is a highly unlikely scenario. As such, we have evaluated the systems implications of LTE's QPSK modulation schemes and see a shift, yet again, for real-world implementation in mobile devices. ***Table 4*** outlines the evaluation points for this higher order data modulation scheme and ***Figure 8*** serves as a composite of the three different PDFs presented.

TABLE III

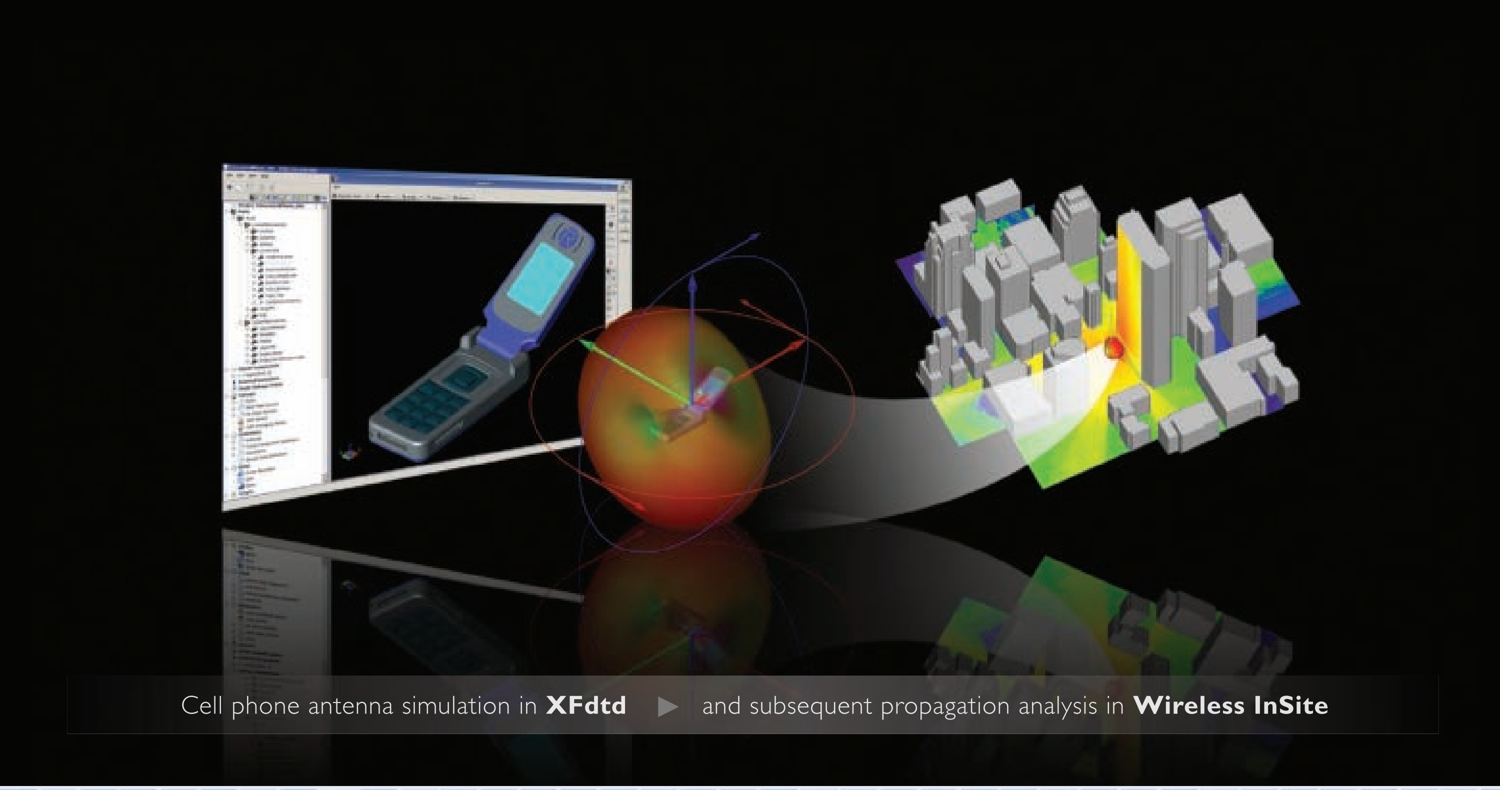
3G DATA PDF EVALUATION POWER LEVELS AND PROBABILITIES

Pant (dBm)	3G.DATA [3G HSPA+] P(x) %
24	8.8
21	5.3
18	8
15	10.6
12	12.2
9	12.9
6	12.2
3	10.6
0	7.9
-3	5.3
-8	3.5
-18	1.5
-28	0.7
-38	0.5

TABLE IV

4G DATA PDF EVALUATION POWER LEVELS AND PROBABILITIES

Pant (dBm)	4G.DATA [LTE QPSK] P(x) %
24	5.3
21	3.5
18	5.3
15	8
12	10.6
9	12.2
6	12.9
3	12.2
0	10.6
-3	7.9
-6	5.3
-11	3.5
-21	1.5
-31	0.7
-41	0.5



Cell phone antenna simulation in **XFdtd** ▶ and subsequent propagation analysis in **Wireless InSite**

A quick analysis of Figure 8 shows the current and upcoming complexity of Smartphone RF, and hopefully it highlights the need to abandon "static" measurements of performance. Even if there is disagreement as to the exact set points for the creation of PDF curves, we believe that utilizing a set of PDFs, however defined, is far better than utilizing a few discrete points to make key architectural and component selection decisions.

NO MORE EXCUSES FOR DOING IT THE RIGHT WAY

Batteries do not stay at the same voltage during the discharge cycle, thus a dynamic environment exists in the mobile phone. By definition, mobile phone users are mobile, providing another, simultaneously dynamic environmental variable. Although we have spent so many years using static measurement points to determine the "goodness" of a front-end solution, one quickly sees that these assumptions are not in line with how the real cellular-based mobile world works.

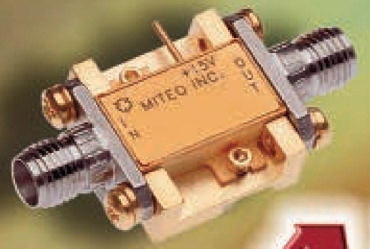
There might be some who say, "But the measurement equipment and time to evaluate such dynamic profiles did not exist." Perhaps not at that time, but they certainly do now. At RFMD®, there are component characterization systems that can evaluate a multi-mode, multi-band environment over all temperature, load and power level conditions in a matter of days; the same amount of information collection would have taken a matter of months previously. The technology is available to allow us to be more exacting in our analysis.

Perhaps most important is that we are at a huge inflection point in our industry. For an industry that has been driven largely by voice, under a minimum number of cellular modulation schemes, the world is changing fast. The growth of Smartphone volume is of the kind of segment growth we have not seen in a decade. And with these new devices comes an extremely dynamic, complex and demanding operating environment. Static, single voltage, single power level measurements to determine the goodness of a solution are archaic at best. Neglect is perhaps a more appropriate term to use considering the millions of dollars of research and development expended each year to develop these RF components.

Should we challenge our industry and RF component suppliers to move quickly to these more dynamic metrics? It seems the prudent choice. The first step is a straightforward one—change the datasheets and show the performance under these new metrics. Only then will original equipment manufacturers (OEM) see where improvements can be made, which will enhance the operational quality of the handsets and mobile devices they create. We invite our fellow suppliers to join us as we send the message—Welcome to the next decade of RF. ■

Ben Thomas *is the director of marketing for 3G/4G Cellular Front Ends at RFMD.*

Jackie Johnson *is the manager of Cellular Front End Applications Engineering at RFMD.*



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Model Number	Frequency Range (GHz)	Gain (Min./Max.) (dB)	Gain Flatness (±dB)	Noise Figure (dB, Max.)	VSWR Input (Max.)	VSWR Output (Max.)	Output Power @ 1 dB Comp. (dBm, Min.)	Nom. DC Power (+15 V, mA)
OCTAVE BAND AMPLIFIERS								
AFS3-00120025-09-10P-4	0.12-.25	38	0.50	0.9	2.0:1	2.0:1	+10	125
AFS3-00250050-08-10P-4	0.25-0.5	38	0.50	0.8	2.0:1	2.0:1	+10	125
AFS3-00500100-06-10P-6	0.5-1	38	0.75	0.6	2.0:1	1.5:1	+10	150
AFS3-01000200-05-10P-6	1-2	38	1.00	0.5	2.0:1	2.0:1	+10	150
AFS3-01200240-06-10P-6	1.2-2.4	34	1.00	0.6	2.0:1	2.0:1	+10	150
AFS3-02000400-06-10P-4	2-4	32	1.00	0.6	2.0:1	2.0:1	+10	125
AFS3-02600520-10-10P-4	2.6-5.2	28	1.00	1.0	2.0:1	2.0:1	+10	125
AFS3-04000800-07-10P-4	4-8	32	1.00	0.7	2.0:1	2.0:1	+10	125
AFS3-08001200-09-10P-4	8-12	28	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-08001600-15-8P-4	8-16	28	1.00	1.5	2.0:1	2.0:1	+8	100
AFS4-12001800-18-10P-4	12-18	28	1.50	1.8	2.0:1	2.0:1	+10	125
AFS4-12002400-30-10P-4	12-24	24	2.00	3.0	2.0:1	2.0:1	+10	85
AFS3-18002650-30-8P-4	18-26.5	18	1.75	3.0	2.2:1	2.2:1	+8	125
MULTIOCTAVE BAND AMPLIFIERS								
AFS3-00300140-09-10P-4	0.3-1.4	38	1.00	0.9	2.0:1	2.0:1	+10	125
AFS2-00400350-12-10P-4	0.4-3.5	22	1.50	1.2	2.0:1	2.0:1	+10	80
AFS3-00500200-08-15P-4	0.5-2	38	1.00	0.8	2.0:1	2.0:1	+15	125
AFS3-01000400-10-10P-4	1-4	30	1.50	1.0	2.0:1	2.0:1	+10	125
AFS3-02000800-09-10P-4	2-8	26	1.00	0.9	2.0:1	2.0:1	+10	125
AFS4-02001800-24-10P-4	2-18	35	2.00	2.4	2.5:1	2.5:1	+10	175
AFS4-06001800-22-10P-4	6-18	25	2.00	2.2	2.0:1	2.0:1	+10	125
AFS4-08001800-22-10P-4	8-18	28	2.00	2.2	2.0:1	2.0:1	+10	125
ULTRA WIDEBAND AMPLIFIERS								
AFS3-00100100-09-10P-4	0.1-1	38	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-00100200-10-15P-4	0.1-2	38	1.00	1.0	2.0:1	2.0:1	+15	150
AFS1-00040200-12-10P-4	0.04-2	15	1.50	1.2	2.0:1	2.0:1	+10	50
AFS3-00100300-12-10P-4	0.1-3	32	1.00	1.2	2.0:1	2.0:1	+10	125
AFS3-00100400-13-10P-4	0.1-4	30	1.00	1.3	2.0:1	2.0:1	+10	125
AFS3-00100600-13-10P-4	0.1-6	30	1.25	1.3	2.0:1	2.0:1	+10	125
AFS3-00100800-14-10P-4	0.1-8	28	1.50	1.4	2.0:1	2.0:1	+10	125
AFS4-00101200-22-10P-4	0.1-12	34	1.50	2.2	2.0:1	2.0:1	+10	150
AFS4-00101400-23-10P-4	0.1-14	24	2.00	2.3	2.5:1	2.5:1	+10	200
AFS4-00101800-25-S-4	0.1-18	25	2.00	2.5	2.5:1	2.5:1	+10	175
AFS4-00102000-30-10P-4	0.1-20	20	2.50	3.0	2.5:1	2.5:1	+10	125
AFS4-00102650-42-8P-4	0.1-26.5	24	2.50	4.2	2.5:1	2.5:1	+8	135

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MEMS Tuner Modules Could Solve Handset Reception Problems

Most people have heard about the iPhone 4 antenna problems. Apple released the new phone with a novel set of external antennas that immediately had reception problems. The company cleverly used the stainless steel band around the phone as the antenna for GSM, UMTS, WiFi, GPS and Bluetooth with spaces separating the multiple antennas around the phone to electrically isolate them (see ***Figure 1***).

Placing the antennas on the outside of the phone seemed like a nice approach that freed up space on the inside and maximized the size of the antennas, which should have helped increase the efficiency at the cellular frequencies. A recent clandestine poll revealed that Apple was not alone in deriving plans for such "edge antenna" designs. The ever-increasing feature sets of smartphones require more space for components and batteries translating into less volume for the antenna. This forces antenna designers to seek novel ways for developing radiating elements.

▲ *Fig. 1 iPhone 4 antennas (courtesy of intomobile).*

Two problems occurred that Apple did not seem to account for in the design. First, touching between the antennas will short them together causing them to perform poorly. Second, covering them up while holding the phone can attenuate the signal to the point where the call is dropped (which can happen with any mobile phone if the area over the antenna is covered). The first problem was solved by giving away free skins or cases that protected the perimeter of the phone so a person's hand would not come into contact with the antennas, but the second one is more universal and difficult to solve. But how was this not discovered in testing? According to an insider, it was found later that the dummy hands used to simulate human use situations in testing are not malleable enough to cover the area between the antennas; human hands, however, are malleable enough to do this.

It is common to design and test for phone reception issues using simulated hand and head positions with special dummies that simulate actual use, but the combinations are infinite

Patrick Hindle
Editor, Microwave Journal


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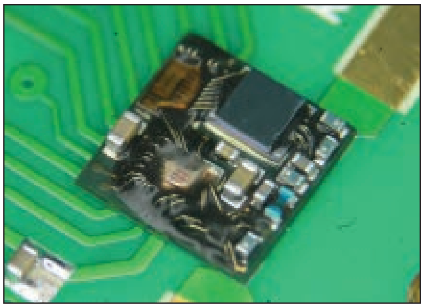
so it is not possible to test all of them. Many current mobile phones do suffer from over-the-air (OTA) performance degradation due to hand and head effects. However, future phones will have to deal with an even greater range of frequencies and modes as 4G technologies come online, which can lead to an even more difficult situation of the overall OTA performance degradation. Therefore, antenna designers need a solution to this problem.

The answer could be adaptive antenna tuners that help solve the performance degradation, while reducing antenna size and current consumption of the mobile phone. If the antenna impedance can be dynamically changed so the antenna is always tuned to the appropriate frequency for maximum efficiency, these problems will be minimized and dropped calls and poor reception will be reduced significantly.

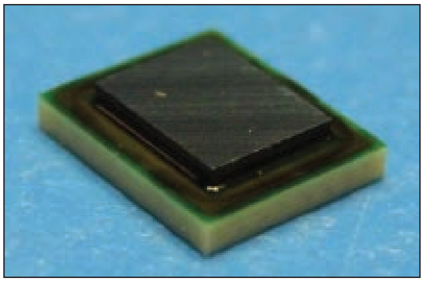


▲ *Fig. 2 TDK-EPC prototype 5 × 5 mm antenna tuner module.*

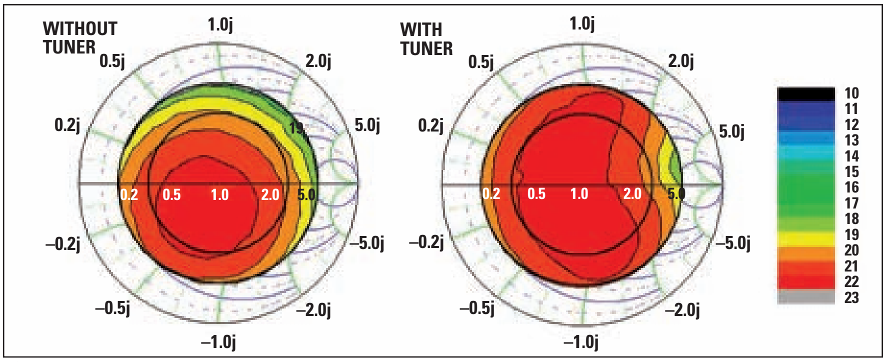
Several companies are working on tunable antenna technologies to solve this problem. Many are using tunable MEMS devices that switch in various values of capacitance to tune the antenna to the desired frequency. There are many devices like varactors that are tunable, but the tuning range is typically not wide enough to cover all the cellular frequencies. Varactors typically tune over a 2:1 range where as MEMS devices are now achieving 10:1 or more, which is needed for the wide range in frequencies that mobile phones utilize. Also, MEMS devices have much higher Q factors than varactors, which are relatively low Q devices. Other key issues for varactors are power handling and linearity as there are 10:1 range varactors, although they have strong nonlinearities.

Some of the MEMS companies involved in this market are TDK-EPC and WiSpry among others. TDK-EPC offers a high performance antenna tuner that employs a closed-loop algorithm that instantly optimizes the matching to the conditions of use. Unlike open-loop systems, the antenna tuner only requires a synchronization signal, making it easy to design into advanced multiband/multimode mobile devices. The adaptive antenna tuner is now in the advanced sampling stage. Pilot production was expected to begin at the end of 2010. It supports all common frequency bands from 824 to 2170 MHz in a module size of 5.0 × 5.0 × 1.0 mm (see ***Figure 2***).

WiSpry recently announced a partnership with IBM to develop single-chip tunable RF front-ends for mobile handsets, which WiSpry will market to tier-one original equipment manufacturers (OEM). The first of these customers was due for initial production before the end of 2010, with others planning production throughout 2011. WiSpry's tunable MEMS tech-



▲ *Fig. 3 WiSpry fully integrated Tunable Impedance Matching (TIM) solution (3.5 × 4.0 mm).*



▲ *Fig. 4 TDK-EPC comparison of RF output power.*

nology uses arrays of capacitive devices that can be quickly tuned in and out to provide over 3 dB of link resilience by adapting to changes in frequency, antenna conditions (such as being touched by the user) and other ongoing operational conditions (see ***Figure 3***). WiSpry's standard RF CMOS manufacturing process through IBM allows for increased integration by building RF MEMS devices on active CMOS silicon structures. This enables a roadmap from discrete RF capacitors all the way to a fully integrated and monolithic single-chip transceiver.

Figure 4 shows a comparison of maximum RF output power of a commercial phone without an antenna tuner (a) and with a tuner (b). Evaluation of RF MEMS technology in antenna tuners by TDK-EPC revealed significantly improved mobile phone efficiency:

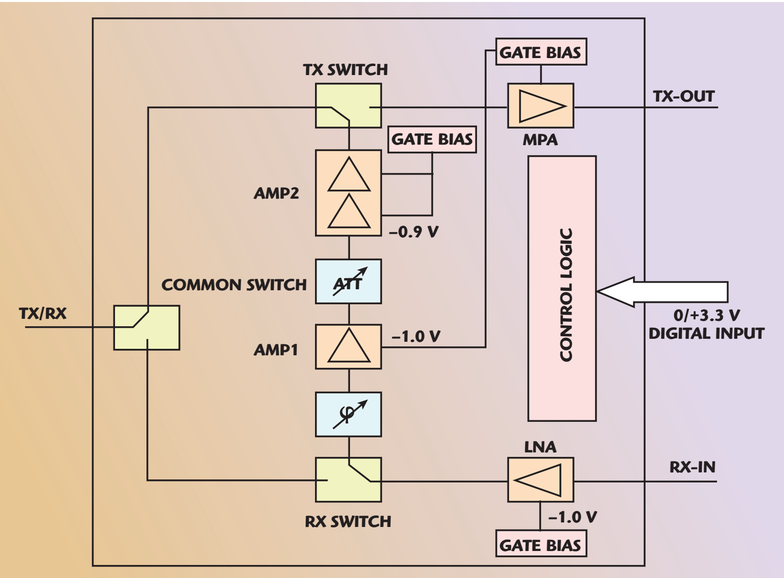
- 50 percent average improvement was observed in both low and high band for a typical commercial phone
- >200 percent average improvement (>800 percent in low band) was also observed for a commercial phone

WiSpry reports similar results with its tuner solution, including a broadband tuning range of 10:1, +3 to +6 dB of transducer gain and overall efficiency gains of 30 percent or more, depending on the implementation within the handset.

iSuppli recently reported that they anticipate RF MEMS revenue to rise to $8.1 M this year, $27.9 M in 2011 and then $223.2 M in 2014. Much of this is projected to be from cell phone front-end adoption of tuning using RF MEMS switches and varactors. There are other technologies competing for this solution, but RF MEMS seem to be leading the way and could see adoption in the very near future. Maybe we can finally get rid of the phrase "Can you hear me now?" ■

8.5 TO 11 GHz HIGHLY INTEGRATED CORE CHIP PROVIDES HIGH DEGREE OF FUNCTIONALITY

When it comes to monolithically integrating functionality, a new benchmark has been set by M/A-COM Tech Asia with the introduction of an X-band, 8.5 to 11 GHz GaAs MMIC core chip for transmit/receive (T/R) modules. This multi-function chip, the XZ1002-BD, consists of fully integrated transmit/receive switches, a low noise amplifier (LNA), a 6-bit phase shifter, a 5-bit attenuator and an output driver amplifier. The core chip also integrates CMOS-compatible digital control circuitry and compensated on-chip gate bias.



▲ *Fig. 1 XZ1002-BD block diagram.*

The block diagram of the highly integrated XZ1002-BD shows the functionality of the device (see ***Figure 1***). The core chip can be operated in either transmit or receive mode by means of the digital control circuit; this circuit also controls the phase and attenuation states in either mode.

The XZ1002-BD delivers high performance across a broad spectrum of parameters. In receive mode, the XZ1002-BD achieves 5.2 dB noise figure, 21 dB gain and +28 dBm OIP3. In transmit mode, the chip has a gain of 22 dB and +23 dBm Psat, with excellent input and output match (see ***Figure 2***). The 5-bit attenuator in

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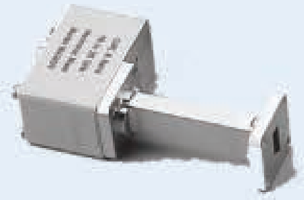
18 to 325 GHz



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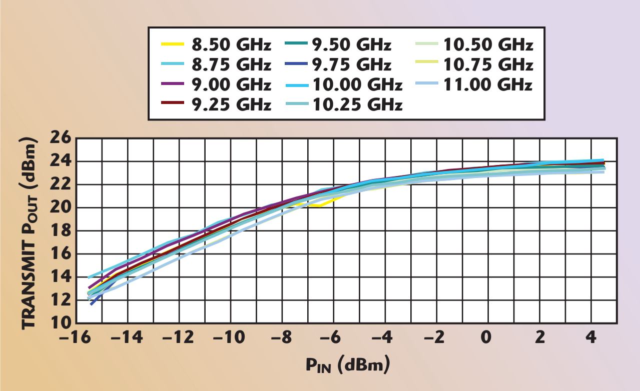
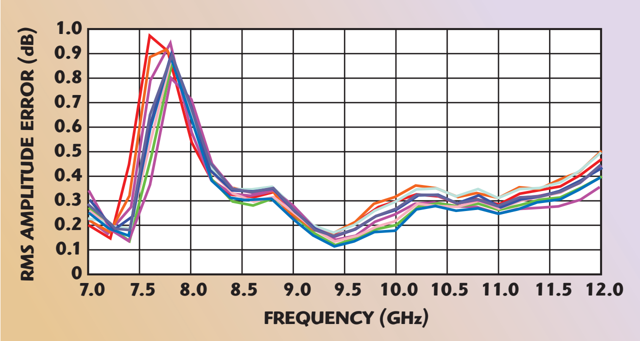


▲ *Fig. 2 Measured large signal performance sample (T_a = 35°C).*



▲ *Fig. 3 Attenuator performance in receive mode (T_a = 35°C).*

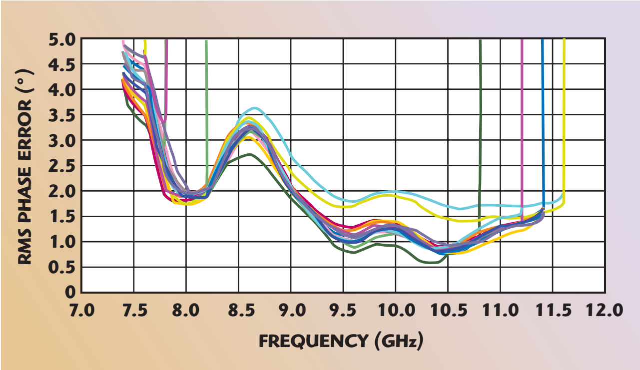
receive mode achieves 28.5 dB attenuation in 32 states. At 10 GHz, the RMS amplitude error of the attenuator is 0.3 dB (see ***Figure 3***); the RMS phase error of the phase shifter is 1.5 degrees (see ***Figure 4***). The 6-bit phase shifter achieves 360 degree range in 64 states.

This highly integrated, unique core chip provides a high degree of functionality and greatly simplifies the design task for transmit and receive modules (see ***Figure 5***), offering many features and benefits for users. The major benefits of this technology include a simpler design, fewer components, smaller board space, lower cost, higher reliability and better control performance.

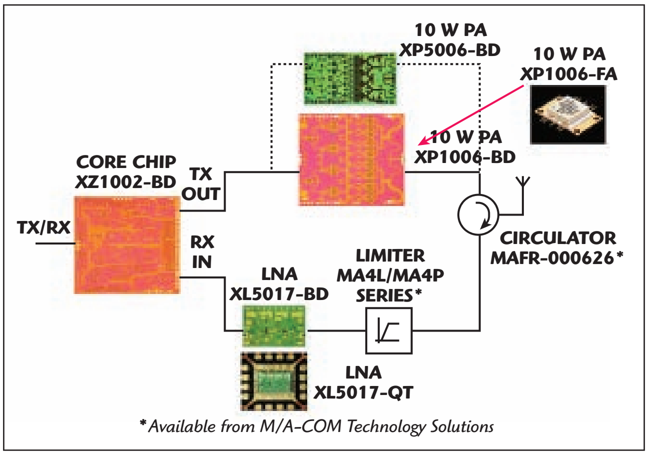
The XZ1002-BD core chip combines up to 10 functions on one device and makes a three-chip phased-array radar T/R module a reality when matched with the XP1006 10 W power amplifier and the best-in-class XL5017 LNA. With these three devices, active X-band phased array and T/R module manufacturers can add an accurate, fast and inexpensive solution to their toolkit.

For additional T/R module options, M/A-COM Tech Asia is also developing a high power amplifier, the XP5006-BD, with power added efficiency (PAE) of 40 percent. Circulators and limiters from M/A-COM Technology Solutions are available to complete the system design if needed. In order to ease and speed up development time, a digitally controlled evaluation board for this core chip is available. The evaluation board can run on a PC with a USB connection.

The XZ1002-BD is designed for applications operating in the 8.5 to 11 GHz range and is well suited for both military and weather phased-array radar applications and satellite communications systems. The integrated on-chip bias



▲ *Fig. 4 Phase shifter performance in receive mode (T_a = 35°C).*



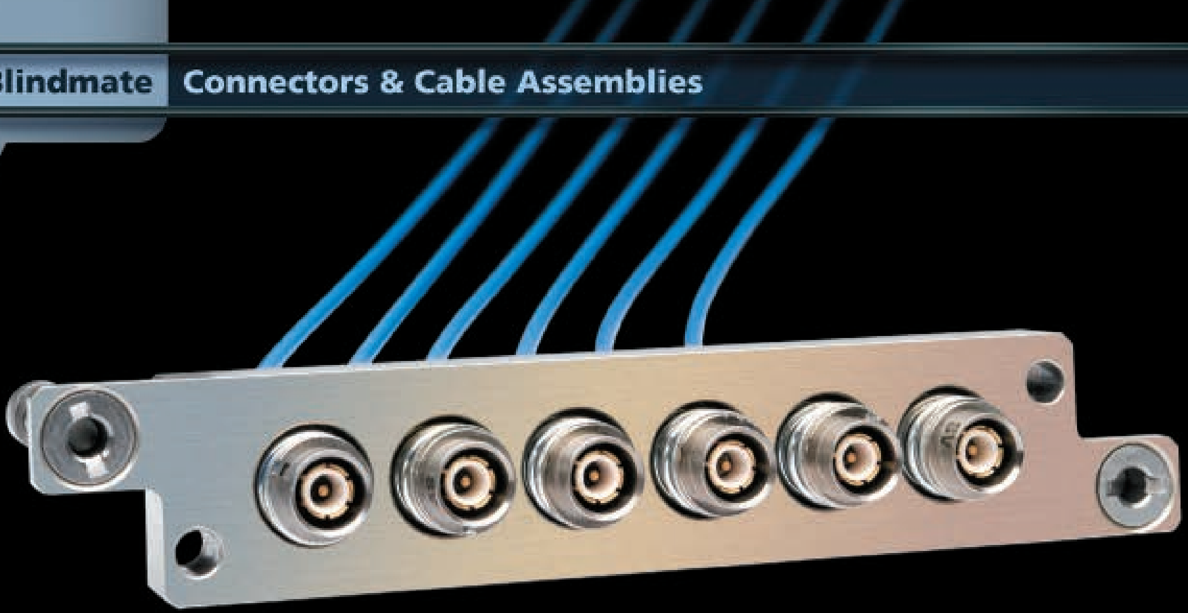
▲ *Fig. 5 X-band chipset for complete T/R module.*

greatly simplifies bias circuitry and overall board complexity, making the design engineer's task much simpler. Furthermore, the careful balance of performance between the 6-bit phase shifter and 5-bit attenuator enables optimized system level performance without increasing the digital processing complexity.

M/A-COM Tech Asia performs 100 percent on-wafer RF, DC and output power testing on the XZ1002-BD, as well as 100 percent visual inspection to MIL-STD-883 method 2010. The chip has surface passivation to protect and provide a rugged part with backside via holes and gold metallization to allow either a conductive epoxy or eutectic solder die attach process.

In summary, M/A-COM Tech Asia's highly integrated core chip, the XZ1002-BD, provides a high degree of functionality and greatly simplifies the design task for T/R modules. The core chip integrates a phase shifter, attenuator, transmit/receive switches, an LNA, a medium power amplifier, digital logic control and on-chip bias circuitry all onto a single GaAs MMIC. The major benefits of this technology include a simpler design, fewer components, smaller board space, lower cost, higher reliability and better control performance. In addition to the X-band XZ1002-BD core chip, M/A-COM Tech Asia offers an S-band chip, the XZ1001-BD. These core chips are ideally suited for phased-array radar applications.

M/A-COM Tech Asia,
Taiwan, ROC
Tel +886-3-567-9680.



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Specifications

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BMA*		DC to 22 GHz
BMMA		DC to 28 GHz
BMZ		DC to 18 GHz
BZ**		DC to 2 GHz
VSWR:		
BMA		1.02 + .008 (f) GHz
BMMA		1.05 + .01 (f) GHz
BMZ		1.05 + .01 (f) GHz
BZ		1.02 + .05 (f) GHz
Insertion Loss:		
BMA		.03 x √(f) GHz
BMMA		.04 x √(f) GHz
BMZ		.06 x √(f) GHz
BZ		.15 x √(f) GHz
Float, Inches (mm):		
BMA	Radial: .020 (.51)	Axial: .060 (1.5)
BMMA	Radial: .020 (.51)	Axial: .060 (1.5)
BMZ	Radial: .020 (.51)	Axial: .060 (1.5)
BMZ	Radial: .020 (.51)	Axial: .150 (3.8)

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** 12.4 and 18 GHz units available.

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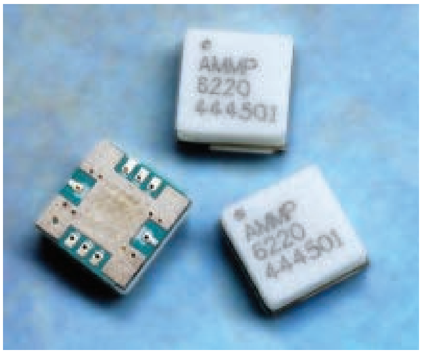

A COMPLETE MMIC CHIP SET FOR 38 AND 42 GHZ APPLICATIONS

Avago Technologies' five-chip monolithic microwave integrated circuit (MMIC) solution, shown in ***Figure 1***, targets the expanding 38 and 42 GHz point-to-point radio markets. This solution enables the end user to source a complete RF front-end solution from a single supplier allowing for fast time-to-market. Avago designs millimeter-wave products in high-performance 5 × 5 surface-mount technology (SMT) packages to enable a robust and automated manufacturing flow.

POINT-TO-POINT WIRELESS MARKETS

The wireless infrastructure market is expanding to meet the increasing demands of cellular customers. Smart phones and tablets are driving an ever-increasing amount of data that must be handled by backhaul networks. Point-to-point microwave is one of the main methods of backhaul deployment around the world besides copper T1/E1, Ethernet over fiber and Ethernet over copper. Microwave is the primary method of backhaul in Asia-Pacific, Western Europe, the Middle East and Africa.

In the areas of the world where 38 GHz (37 to 40 GHz) microwave backhaul is deployed, the network is already approaching capacity issues. Network operators are therefore looking to overlay 42 GHz (40.5 to 43.5 GHz) as a new microwave band to provide extra high-capacity short haul radio links. Packaging can pose a key difficulty in providing a robust manufacturable RF solution at 42 GHz where traditional plastic lead-frame solutions no longer work effectively. In this application, Avago's fully matched, air cavity laminate 5 × 5 mm package offers an advantage for achieving high performance.

MANUFACTURING CAPACITY AND CHIP SET DESCRIPTION

The MMIC designs are fabricated using Avago's proprietary 0.17 micron gate Pseudomorphic High Electron Mobility Transistor (PHEMT) process. With >80 GHz FT transis-

AVAGO TECHNOLOGIES INC.
San Jose, CA

MMIC AMPLIFIERS

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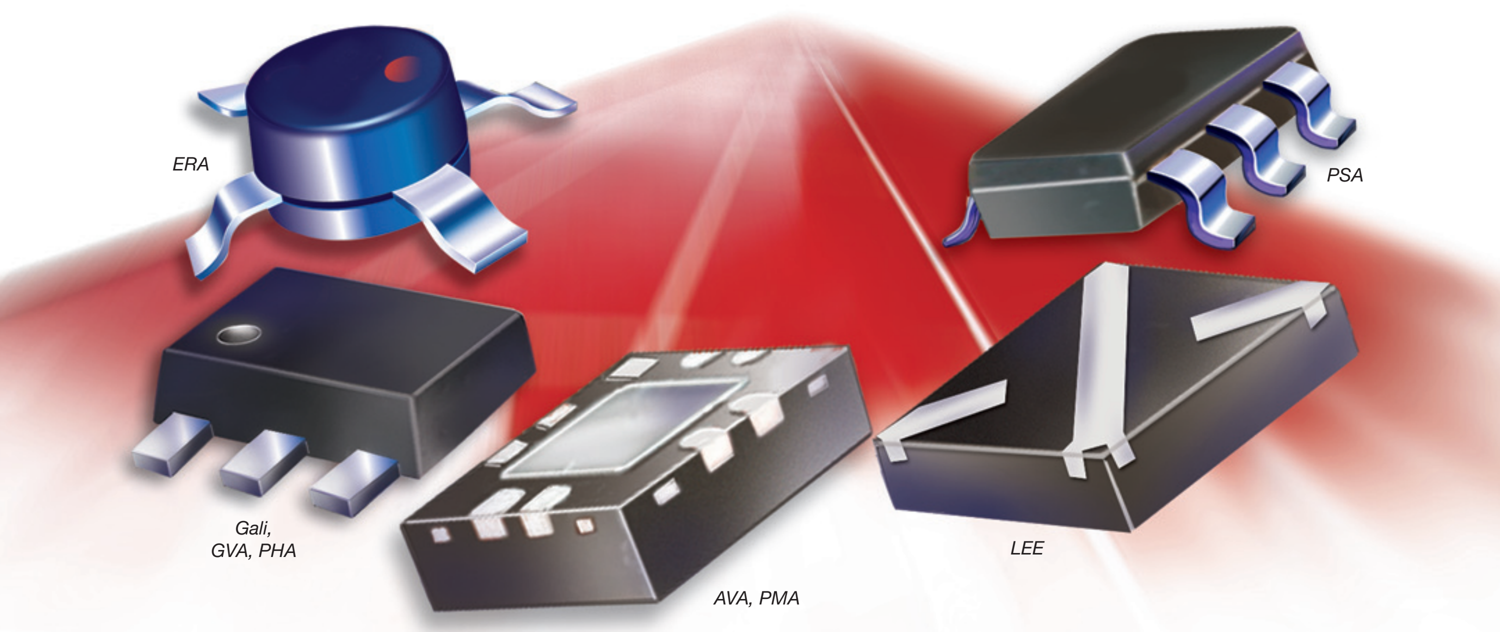

NF from 0.5 dB, IP3 to +48 dBm, Gain 10 to 30 dB, Pout to +30 dBm

Think of all you stand to gain. With more than ~~120~~ 124 catalog models, Mini-Circuits offers one of the industry's broadest selection of low-cost MMIC amplifiers. Our ultra-broadband InGaP HBT and PHEMT amplifiers offer low noise figure, high IP3, and a wide selection of gain to enable optimization in your commercial, industrial or military application.

Our tight process control guarantees consistent performance across multiple production runs, so you can have confidence in every unit. In fact, cascading multiple amplifiers often produce less than 1dB total gain variation at any given frequency. These MMIC amplifiers can even meet your most critical size and power consumption requirements with supply voltages as low as 2.8 V, and current consumption down to 20 mA, and packages as small as SOT-363.

Visit our website to select the amplifier that meets your specific needs. Each model includes pricing, full electrical, mechanical, and environmental specifications, and a full set of characterization data including S-Parameters. So why wait, place your order today and have units in your hands as early as tomorrow. RoHS compliant

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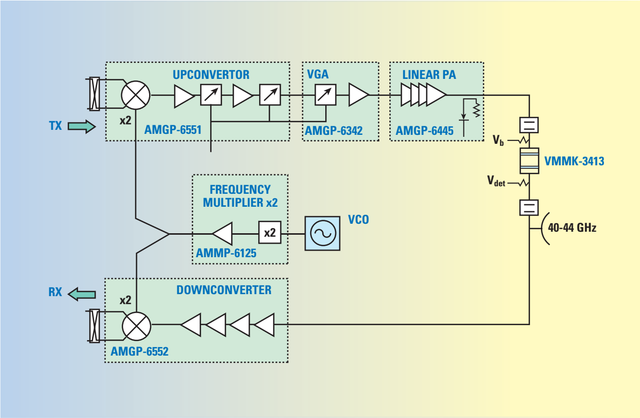
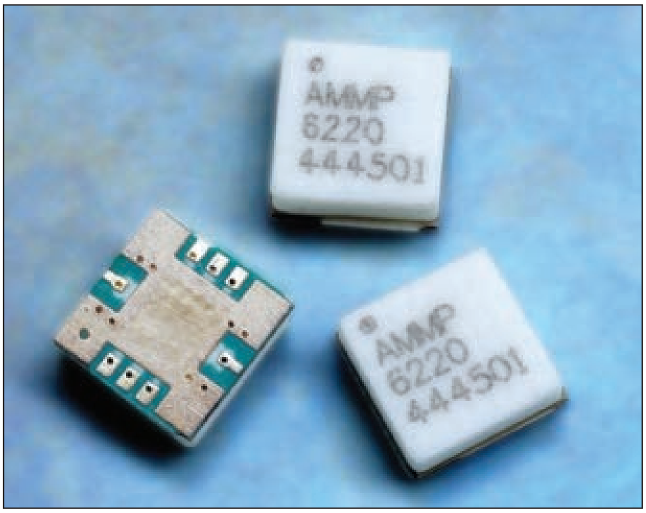
IF/RF MICROWAVE COMPONENTS

476 Rev C



▲ *Fig. 1 Avago 38 and 42 GHz MMIC chip set block diagram.*



▲ *Fig. 2 Avago MMIC chip set packaged in 5 × 5 mm SMT packages.*

tors, this process is more than capable of meeting the applications at 40 GHz frequencies. Manufactured in Avago's high-yield, high-volume, 6-inch wafer processing facility, the primary chips are packaged in 5 × 5 mm SMT packages (see ***Figure 2***). The manufacturing and test operation is fully automated and capable of supplying millions of chips per month.

AMGP-6551 UP-CONVERTER/VGA

The AMGP-6551 uses a balanced sub-harmonic approach to reduce local oscillator (LO) leakage that may appear on the RF signal, thus easing filter requirements. Based on a single balanced SH-SSB mixer followed by an amplifier-attenuator-amplifier-attenuator-amplifier, it features low-noise figure, good linearity, conversion gain and gain control.

High input linearity is achieved by distributing gain and loss stages so none are saturated. Low distortion is achieved by having the attenuator FET never enter the nonlinear range. This is done by employing a "lossy-line" approach that sequentially adds more and more loss to the signal as the shunt FET is turned on, but without ever getting close to the nonlinear pinch-off region.

Over the 37 to 44 GHz range, the AMGP-6551 provides 12 dB typical up-conversion gain with 24 dB of gain control. 50 Ω RF/LO match is achieved at all ports and the

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Massachusetts Bay Technologies, Inc. (MBT) specializes in the design, manufacture and distribution of RF/Microwave semiconductor diodes. MBT is committed to the continuance of innovations in service to its customers, improvement of design, product performance and quality control.

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TABLE I

AVAGO MMIC CHIP SET PERFORMANCE

Parameter	Up-Converter	Down-Converter	Power Amp	Multiplier	VGA	Detector
Gain (dB)	12	14	21	21	9	
Insertion Loss (dB)						0.8
Noise Figure (dB)		4.5			10	
Gain Dynamic Range (dB)	24				35	
2x LO Leakage (dBc)	22			15		
Return Loss (dB)	12	12	12	10	10	17
OIP3 (dBm)	17	9	35		25	
P-1dB (dBm)			29			
Sideband Rejection (dBc)	6					
Image Rejection (dB)		17				
Voltage (V)	5	3	4	5	5	1.5
Current (mA)	300	100	800	210	205	1

typical output third-order intercept point is +17 dBm. The AMGP-6551 is housed in a 5 × 5 mm SMT package and operates from a 5 V supply, drawing 300 mA typical.

AMGP-6552 DOWN-CONVERTER

The down-converter consists of a four-stage low noise amplifier (LNA) combined with a sub-harmonic pumped image rejection mixer. The LNA is fed into an RF in-phase power divider in the mixer. From the power divider the signals are fed into one side of anti-parallel diode pairs to produce sub-harmonic pumping. The other side of the anti-parallel is pumped from a LO split using a Lange coupler. A LO buffer amplifier is not used since unwanted second harmonics can easily be produced here and self-mix down to near the intermediate frequency (IF). Over the frequency range it provides 14 dB typical down-conversion gain. Typical noise figure of 4.5 dB is achieved and typical input IP3 is -5 dBm.

AMGP-6445 POWER AMPLIFIER

The AMGP-6445 MMIC linear power amplifier (PA) is a four-stage design with three separate gate and drain supplies for optimum bias. It is designed for transmitters that operate between 40 and 44 GHz. In the operational band, it provides typical 29 dBm of output power (P-1dB) and 21 dB of small-signal gain. The AMGP-6445 device is also designed for high linearity applications, and the PA shows typical +35 dBm OIP3.

The input, inter-stage and output matching circuits are composed of pre-matching circuits and impedance transformers. The final power combiner is critical to phase-match eight separate FETs to combine the total power into one cohesive output.

AMMP-6125 LO BUFFER WITH FREQUENCY MULTIPLIER

The AMMP-6125 local oscillator is an easy-to-use integrated frequency multiplier (×2) in a surface-mount package. The MMIC takes a 5 to 13 GHz input signal and doubles it to 10 to 26 GHz. It has integrated amplification, matching, harmonic suppression and bias networks. The input/output are matched to 50 Ω and fully DC blocked. The frequency multiplier is a differential amplifier that acts as an active balun. The outputs are connected so that even drain currents are in phase and thus add power, and odd harmonics are out of phase and thus suppressed.

AMGP-6342 VARIABLE GAIN AMPLIFIER (VGA)

The VGA uses an attenuator-amplifier topology to maximize linearity, gain and gain control in a 5 × 5 mm SMT package. Suitable for 27 to 44 GHz applications, small-signal gain is 9 dB typical (37 to 44 GHz) and gain dynamic range is 35 dB typical. Operating from a 5 V supply current draw is 205 mA typical.

VMMK-3413 POWER DETECTOR

The power amplifier includes a simple built-in resistive power detector, as most power amplifiers do, and it is useful for a gross "on or off" system level power detection; however, since it is resistive, it has only limited range and no directivity. Many modern forward-correction systems require knowledge of the actual power being transmitted independent of antenna load. The Avago directional temperature compensated power detector is suitable for handling these types of applications. The VMMK-3413 detector uses a very high tolerance coupler combined with a DC differential amplifier connected to an internal diode reference. A wafer-scale package is used for low cost and for small size (0.5 × 1.0 mm).

The detector's insertion loss is only 0.8 dB typical in the 42 GHz band. The detect voltage is 0 to 3 V over a -5 to +25 dBm power range. The 8 dB directivity allows true transmit power measurement compared to resistive power detectors that have no isolation from reflections. Operating from 1.5 V, current draw is typically only 0.15 mA.

CONCLUSION

A performance summary for the chip set is shown in ***Table 1***. The MMIC family allows designers to source a complete 38 to 42 GHz radio solution in surface-mount technology from one vendor for better quality control, application support and shorter time to market.

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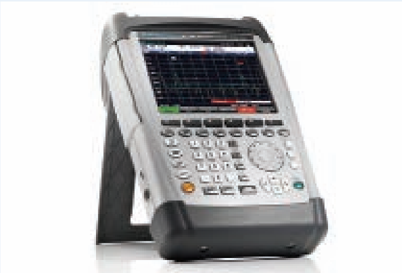

Handheld Cable and Antenna Analyzer Reduces Antenna Station Installation Time

The rapid expansion of mobile radio networks has required network operators to increase mobile radio antennas and base stations, often under strict time and cost constraints. The new R&S ZVH handheld analyzer from Rohde & Schwarz was designed especially to meet such demands. Two frequency ranges, from 100 kHz to 3.6 GHz or 8 GHz, are available.

Even in its basic configuration, the handheld analyzer detects cable faults, measures the matching of filters and amplifiers, and checks the loss of cable connections. For further measurements such as the isolation between transmit and receive antennas or the output power of output amplifiers, options are available.

The analyzer incorporates wizards that guide users through procedures in individual, well described steps. Network operators can adapt the wizards in the lab to their individual test report formats and make them available for use on site. Predefined test reports in various file formats make it easy to demonstrate that assignments were properly executed.

The fact that the R&S ZVH has a dynamic range of 100 dB means that it easily fulfils manufacturer's guidelines of >90 dB required for repeater measurements. The built-in DC bias supplies power to active DUTs, such as amplifiers, at both test ports via the RF cable.

The 194 × 300 × 69 mm instrument weighs 3 kg and frequently used functions have their own function keys. The color display is easy to read and there is a monochrome mode for extreme conditions. The capacity of the battery enables uninterrupted operation for up to 4.5 hours. The analyzers conform to protection class IP51 and feature splash-proof, dust-protected connectors.

The R&S ZVH comes with options for spectrum and network analysis and spectrogram display, which cover applications such as spectrum analysis, field strength measurements, signal monitoring and interference hunting. Using external power sensors, it can also operate as a power meter. When used with a directional power sensor, the analyzer can simultaneously measure antenna matching and transmitter output power up to 300 W.

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141-3SM+	3	0.23	38	8.69
141-4SM+	4	0.14	35	8.69
141-5SM+	5	0.19	37	8.69
141-6SM+	6	0.25	39	8.69
141-7SM+	7	0.33	37	8.69
141-8SM+	8	0.30	38	8.69
141-9SM+	9	0.38	38	8.69
141-10SM+	10	0.39	37	8.69
141-12SM+	12	0.46	38	9.70
141-14SM+	14	0.52	37	9.70
141-15SM+	15	0.54	37	9.70
141-18SM+	18	0.62	37	9.70
141-24SM+	24	0.77	37	11.70
.086" Diameter				
086-3SM+	3	0.20	33	8.95
086-4SM+	4	0.23	33	8.95
086-5SM+	5	0.29	33	8.95
086-6SM+	6	0.34	34	8.95
086-7SM+	7	0.42	32	8.95
086-8SM+	8	0.46	36	8.95
086-9SM+	9	0.54	33	8.95
086-10SM+	10	0.58	35	8.95
086-12SM+	12	0.69	36	9.95
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GaN FETs boast a maximum junction temperature of 250°C, translating into higher operating temperatures without adversely affecting the MTBF. The amplifier shuts off when base plate temperature exceeds +100°C and also has an over-voltage protection shutoff above 37 V. The rugged design even tolerates open or shorted output loads with no damage to the amplifier. Applications include VHF/UHF transmitters, defense projects, ham radio, FM, TV and laboratory use. The amplifier is RoHS compliant in accordance with EU Directive (2002/95/EC) and is available with and without cooling unit in a coaxial package.

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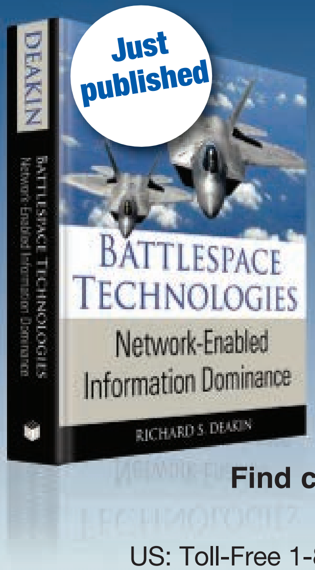


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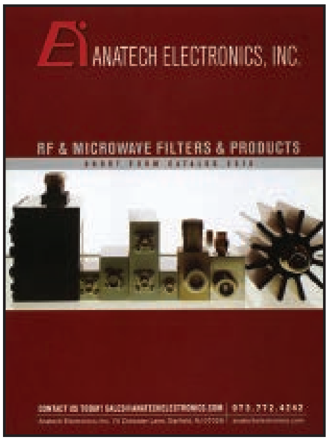

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Agilent Technologies Inc.,
Santa Clara, CA (800) 829-4444, www.agilent.com.

EMC and RF Testing Catalog

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AR has created a new catalog that combines product information from six different brochures for all of AR RF/Microwave Instrumentation. The catalog is easy to use, with "find-it-fast" charts and color coding to help get right to whatever you need for RF and EMC testing. It is available for free download, either in full or by section, at www.ar-worldwide.com.

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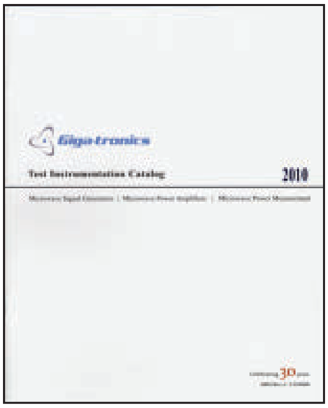


Short Form Product Catalog

The new instrumentation short form catalog contains key product information covering microwave signal generators, microwave power amplifiers and microwave power measurement. The catalog is available on the Giga-tronics website.

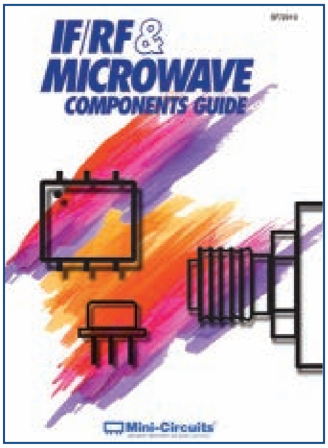
Giga-tronics Inc.,
San Ramon, CA (925) 328-4650, www.gigatronics.com.

Selection Guide

VENDORVIEW

Hittite Microwave Corp. announced the release of its product selection guide that summarizes over 875 products including 68 new products and four new product lines. New for this publication is an expanded product line section featuring wideband power amplifiers, broadband time delay, active bias controller, Mux/DeMux and I/Q upconverter with VGA. This selection guide also contains a new part number index, product sections organized by IC products, connectorized modules and instrumentation and expanded market and application sections.

Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343, www.hittite.com.



IF/RF and Microwave Components Guide

VENDORVIEW

Mini-Circuits' new 164-page catalog includes over 750 new products and is the industry's most comprehensive listing of RF/IF and microwave components and subsystems with more than 4100 products and over 25 product lines including state-of-the-art amplifiers, mixers, VCOs, synthesizers, filters, test accessories and USB power sensors; also a new section on custom integrated RF/microwave assemblies and the company's Partner Program rewards plan. Mini-Circuits' website provides additional data, application notes, design tools and its powerful YONI search engine that searches actual test data on over thousands of units.

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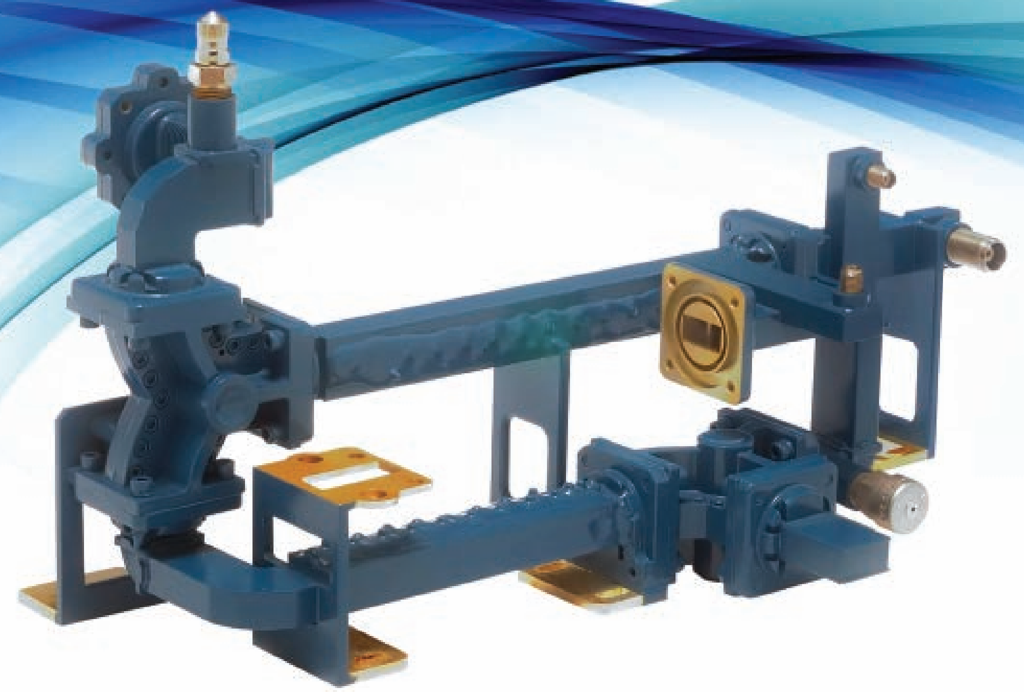

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Transmit Loss ....1.0 DB Max.

Receive VSWR.......1.50 Max.

Receive Loss.........1.0 DB Max.

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Power (Peak) 300W

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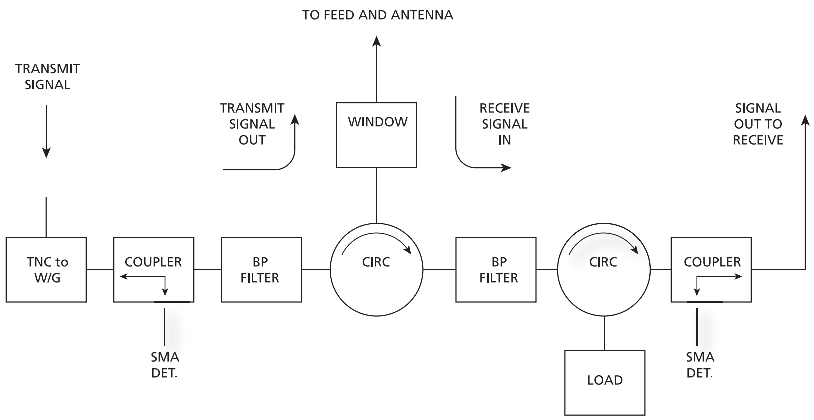

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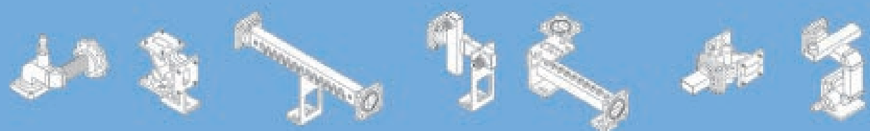
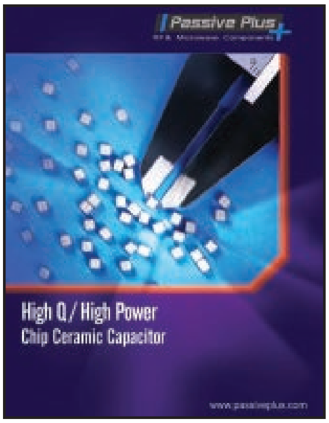


Microwave Development Laboratories
135 Crescent Road
Needham Heights, MA 02494

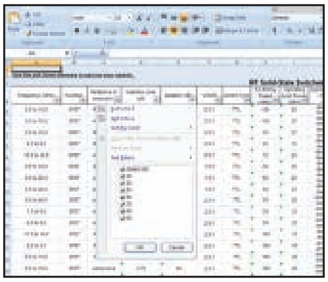
V: 781-292-6680/6684
F: 781-453-8629
E-mail: mdlsales@mdllab.com
www.mdllab.com



Product Catalog

Passive Plus has released a new Hi-Q Capacitor Catalog that includes updated performance curves, additional new case sizes and an expanded non-magnetic component offering. The new catalog also details all the variations in which its products can be ordered. Contact sales@passiveplus.com to get your copy today. Passive Plus is also currently constructing its buy online facility where you will be able to purchase the company's products and design kits directly through the site. Watch the company's website for breaking details.

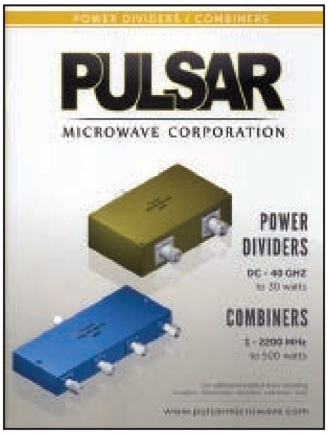
**Passive Plus Inc.,
Huntington Station, NY (631) 425-0938, www.passiveplus.com.**



Product Selection Guide

This product selection guide contains a complete listing of all PMI standard products, including amplifiers, filters, switch filter banks, switch products, limiters, phase shifters, SDLVAs, threshold detectors, couplers and power dividers. The search by product type and specification feature allows quick location of the device you need. Direct web links are included that allow easy website viewing, which contains specification listings, data and test reports.

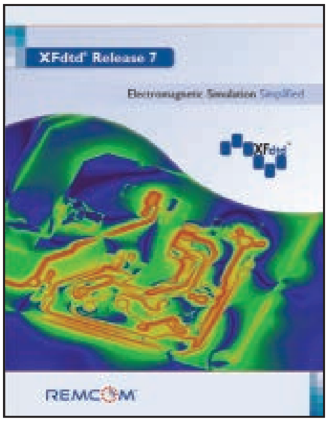
**Planar Monolithics Industries,
Frederick, MD (301) 662-5019, www.pmi-rf.com.**



Power Dividers and Combiners

Pulsar has an extensive line of power dividers and combiners in lumped element, microstrip and stripline designs in surface-mount, drop-in and connectorized configurations. Pulsar's enormous library of designs allows for modifications of standard designs to be made quickly and inexpensively with short delivery times.

**Pulsar Microwave Corp.,
Clifton, NJ (973) 779-6262, www.pulsarmicrowave.com.**

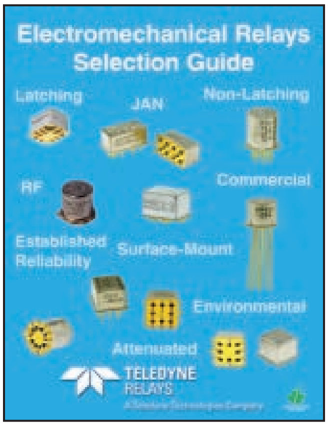


Electromagnetic Simulation Simplified

VENDORVIEW

Remcom's XFdtd® 7 (XF7) is the market's most modern 3D electromagnetic simulation software for FDTD-based modeling and simulation. Discover the Top 10 Benefits of XF7 in this detailed brochure that outlines how XF7 provides a better user experience via a simplified workflow, streamlined user interface, cross-platform functionality, and several unique time-saving features.

**Remcom Inc.,
State College, PA (888) 7-REMCOM, www.remcom.com.**



Electromechanical Relays Selection Guide

This guide is designed for engineers to aid quick product selection and details the company's RF, commercial, military (JAN), special environment and established reliability relays. Included are comprehensive descriptions, schematic diagrams and mounting options for each relay series. A comparative read across table of screening levels for established reliability and military relays is provided as well as information for space qualified relays. Particular attention has been paid to the RF relays with the inclusion of signal integrity eye diagrams to demonstrate the digital transmission capabilities of the RF relays.

**Teledyne Relays,
Cumbernauld, Scotland +44 (0)1236 453 124,
www.teledyne-europe.com.**

Product Catalog

Times Microwave Systems has just released the latest edition of its popular CD-ROM that includes several new and updated brochures and catalogs including the newest edition of the LMR® Wireless Products Catalog, which now includes the innovative new Times-Protect™ line of RF surge and lightning protection products as well as new SilverLine test cable products. The Times Microwave Systems CD-ROM features an easy-to-use menu for navigation within each catalog. There are also invaluable 'how-to' installation videos including several new ones to assist users of LMR low loss coaxial cable products and two handy calculators for determining both coaxial cable attenuation and conversion of VSWR-to-return loss.

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

New Waves: Radar and Antennas

For more new products, visit www.mwjournal.com/buyersguide
featuring VendorView storefronts

GaAs MMIC SP4T Switches
VendorView

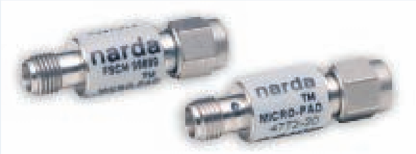
These two new SMT packaged GaAs PHEMT MMIC SP4T switches are ideal for industrial sensors, test and measurement, microwave radio, military EW and space applications up to 30 GHz. The HMC641LP4E is a MMIC SP4T switch that is rated for operation from DC to 20 GHz. This wideband, non-reflective switch exhibits 2.3 dB insertion loss and 42 dB isolation at midband, and features an on-chip binary decoder that requires only two 0/-5 V control lines. The HMC944LC4 is a MMIC SP4T switch that is rated for operation from 23 to 30 GHz. This compact Ka-band switch exhibits 2.8 dB insertion loss and 35 dB isolation, and features fast switching speed of only 53 ns. The HMC944LC4 is controlled with 0/-3 V logic and consumes much less DC current than a PIN diode-based solution.
Hittite Microwave Corp.,
Chelmsford, MA
(978) 250-3343,
www.hittite.com.

High Power Pulsed Transistor

Integra Technologies demonstrates the advantages of LDMOS technology in pulsed radar applications. The high power pulsed transistor part number ILD2731M200 is designed for S-band systems operating from 2.7 to 3.1 GHz. Operating at a pulse width of 300 μs with a duty factor of 10 percent, this device supplies a minimum of 200 W of peak pulse power across the instantaneous operating bandwidth of 2.7 to 3.1 GHz. The ILD2731M200 will be released and available for sampling in Q4 of 2010. The high power pulsed transistor part number ILD3135M180 is designed for S-band systems operating from 3.1 to 3.5 GHz. Released in Q3 of 2010, the ILD3135M180 is available for immediate sampling now.
Integra Technologies Inc.,
El Segundo, CA
(310) 606-0855,
www.integratech.com.

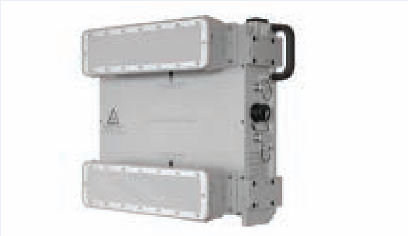
Fixed 3 dB Attenuator
VendorView

Narda introduced the model 4772-3 miniature fixed 3 dB attenuator that has flat frequency



response, low VSWR and meets environmental requirements for MIL-A-3933. The attenuator measures only 1.24" × 0.38" and weighs 0.5 oz. It handles 2 W average and 200 W peak power, with a VSWR of 1.4:1 or less and attenuation deviation of ±0.3 dB or less. Connectors are stainless steel SMA female. The model 4772-3 attenuator is available for immediate delivery.
Narda,
Hauppauge, NY
(631) 231-1700,
www.nardamicrowave.com/east.

E-scan Surveillance Radars



The Blighter B400 series is the company's latest generation of e-scan surveillance radars (GSR), which can scan and detect moving vehicles and people (including crawlers) over a wide area and provide good range performance out to 32 km. Blighter radars incorporate a combination of FMCW and Doppler processing technology ensuring ground clutter cancellation. They are all-in-one fully integrated units comprising antennas, signal processing, plot extractor, GPS and compass. They are designed to withstand harsh environmental conditions, and include a built-in precipitation filter that suppresses false detection from rain and snow. Day/night 24 hour operation is fully supported.
Plextek Ltd.,
Great Chesterford, UK
+44 (0)1790 533200,
www.blighter.com.

Power Transistors
VendorView

RFMD has production released the RF3932, a 75 W, highly efficient gallium nitride (GaN) RF unmatched power transistor (UPT) that delivers superior performance versus competing GaAs and silicon power technologies. The release of the RF3932 follows the recent release of the 140 W RF3934, which is the highest output power device in RFMD's UPT family. RFMD plans to release a third GaN UPT device in the first calendar quarter of 2011, significantly expanding the GaN power transistor options available to RFMD's customers.
RFMD,
Greensboro, NC (336) 664-1233,
www.rfmd.com.

Hybrid Ferrite Transmitter Combiners

Sinclair's new TCC series compact hybrid ferrite combiners offer economical combining solutions for systems requiring extremely close frequency separation and space-efficient racking. The combiner is assembled on a very small 1U high tray. Each unit allows 2 or 4, 60 W transmitters to be combined with one antenna. The UHF and 700/800/900 MHz band TCC series features broad bandwidth that can combine a wide range of transmitter frequencies. These frequencies can be changed without having to re-tune the combiners. The VHF band TCC series offers a bandwidth of 3 MHz, which can be customer adjusted within ±5 MHz of the factory tuned frequency.
Sinclair Technologies Inc.,
Aurora, Ontario, Canada
(800) 263-3275,
www.sinctech.com.

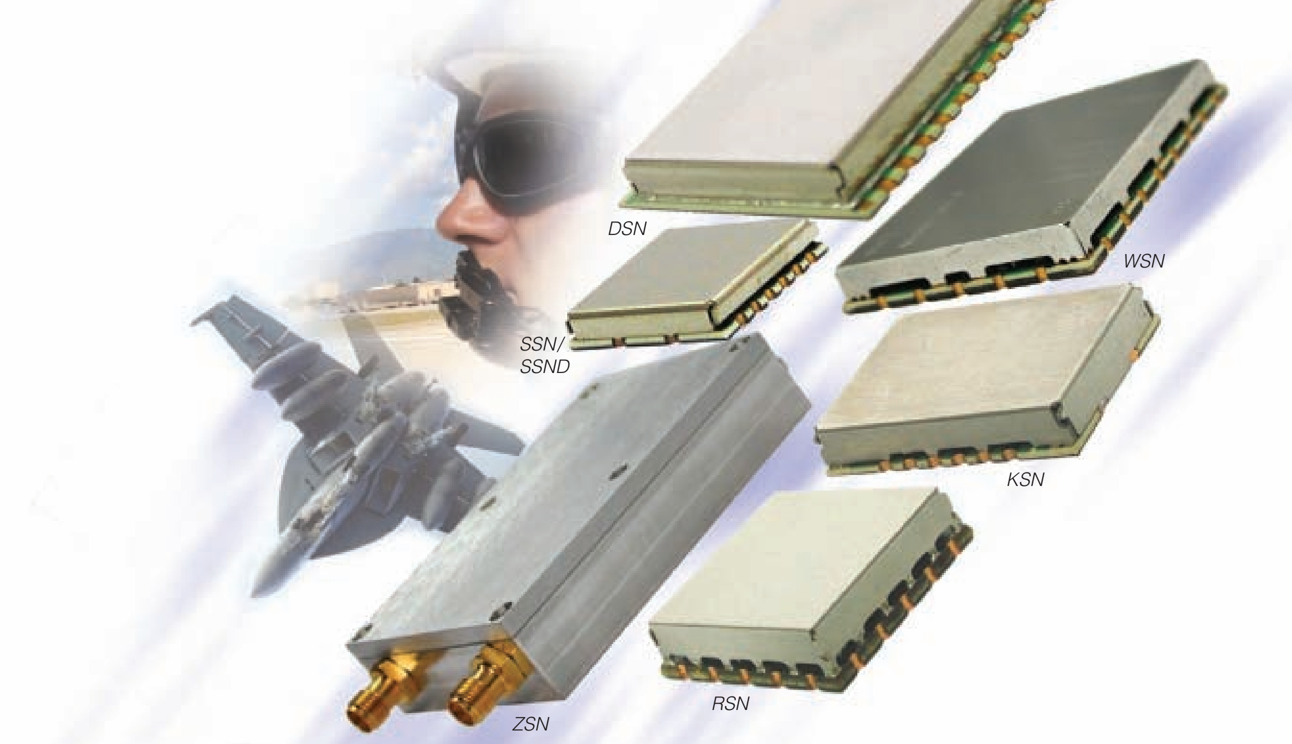
Indirect/DDS Synthesizer

The model SYN151 offers an extremely low profile, thermally managed, quick removal line replaceable unit (LRU) that is ideal for harsh airborne environments. The selectable L-band (±100 MHz) output port provides sub-hertz step size and less than 200 μs switching speed. Phase noise performance is <-100 dBc/Hz at 1 MHz offset from carrier, with -80 dBc spurious (1 to 80 MHz offset) and output power of +11 dBm. This unit provides excellent performance over an operating temperature range of -54° to +76°C.
TRAK Microwave,
Tampa, FL
(813) 901-7200,
www.trak.com.

OVER 100 MODELS... OFF-THE-SHELF

SYNTHESIZERS

56 to 7800 MHz



7 Different Types of Synthesizers from $29.95 qty. 1-9

Offering the needs of a wide range of systems and applications

- *Fixed Frequency*
- *Tunable Narrow Bandwidth*
- *Tunable Medium Bandwidth*
- *Tunable Wide Bandwidth*
- *Tunable Very Wide Bandwidth*
- *Tunable Fast Settling Time*
- *Dual Frequency*

Photos: Courtesy of U.S. Navy and NASA

Mini-Circuits is an industry leader in synthesizer designs with over 250 standard catalog models and many more custom units designed into major programs supporting a wide range of applications.

TDSCDMA CDMA Repeaters WCDMA EDGE GSM TDMA PCS UMTS L-Band Satellite Wireless LAN Point-to Point Radio Test Equipment Microwave Radio High Data Transfer Rates

Need a custom model? Please contact our applications department.

We invite you to visit our Website and view our standard models containing comprehensive performance curves, data sheets, PCB layouts, and environmental specifications. ALL catalog models are available for immediate delivery, direct from our web store. Have a unit in your hands for test and integration as early as tomorrow.

Mini-Circuits...Your partners for success since 1969

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P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

YONI2® ***The Design Engineers Search Engine*** *finds the model you need, Instantly* • For detailed performance specs & shopping online see **minicircuits.com**

U.S. patent 7739260

IF/RF MICROWAVE COMPONENTS

477 Rev. B

Components

Low Cost Resistive Components

Anaren Inc. announced that it has launched a new line of low-cost resistive components designed specifically for commercial wireless bands such as GSM, 3G, 4G, LTE and popular narrow bands between DC to 6 GHz. The line of SMD, chip, flanged, and flangeless components also offers compact packaging (as small as 0.05" × 0.1"), RoHS-compliant materials, and electrical performance advantages like high-power handling (up to 250 W) and low return loss that are so important to next-gen base station equipment providers. With the new line, Anaren is moving from a resistive components offering that caters to all potential markets in order to focus on delivering design, performance, and cost advantages specific to the commercial wireless, high volume/low cost segment.

Anaren Inc.,
East Syracuse, NY (315) 432-8909,
www.anaren.com.

6 dB Directional Coupler

The AM1650DC838 directional coupler is designed for wireless and general-purpose applications from 800 to 2500 MHz. The AM1650DC838 provides 6 dB of coupling with flatness of ±1 dB from 800 to 2500 MHz, insertion loss of 1.5 dB or less, a VSWR of 1.2:1 or less, and 40 W power handling ability. Directivity is 20 dB, isolation is at least 20 dB, and intermodulation distortion is better than -140 dBc. It uses Type N connectors and measures 4.2" × 1.6" × 0.9".

Anatech Electronics Inc.,
Garfield, NJ
(973) 772-4242,
www.amcrf.com.

SMA Connectors

CarlisleIT now offers an Enhanced Performance SMA connector series (EPSMA™) that provides mode free performance to 27 GHz. In addition, these connectors are tuned to provide ultra low VSWR to 27 GHz (typically 1.15:1). This new product offering consists of field replaceable styles with industry standard flange configurations and pin sizes; low RF leakage (less than 90 dB); and all interfaces conform to MIL-STD 348. Common configurations are in stock and available for immediate delivery.

Carlisle Interconnect Technologies,
St. Augustine, FL (904) 829-5600,
www.carlisleit.com.

Thin Film Ceramic Filters

DLI has introduced to the market its Thin Film Technology. DLI offers low pass and high pass filters, ceramic cavity filters and notched filters along with duplexers and diplexers. All filters employ DLI's high-K ceramics that allow for size reduction and temperature stability compared to alumina and PWB materials. Solder surface-mount and chip and wire filters are all possible.

Dielectric Laboratories Inc.,
Cazenovia, NY
(315) 655-8710,
www.dilabs.com.

Low PIM Terminations

Florida RF Labs introduces a new line of high power terminations with low passive intermodulation (PIM) distortion levels. Due to higher demand in frequency spectrum usage, higher transmitter power levels and more sensitive receivers in modern telecommunication systems, PIM distortion has become a potential problem for design engineers globally. These new products are the only terminations available in the market that are guaranteed to have low PIM levels; it is part of the standard specifications and all products are 100 percent tested to guarantee the best performance. Datasheets and samples are available upon request. All products are available RoHS and REACH compliant.

Florida RF Labs,
Stuart, FL (772) 286-9300,
www.rflabs.com.

Variable Attenuators

The 50BA-series is an all-new line of variable attenuator systems. These plug-and-play modules come complete with Ethernet/RS-232 interfaces as well as manual control (via Momentary Lever Actuator Switches with 7-segment digital display). Designed to be easy to use, compact and affordable, the 50BAs are available with one or two channels of attenuation (0 to 63 dB or 0 to 95 dB in 1 dB steps) and operate from 0.2 to 6 GHz. Custom designs are also available.

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

Hybrid Microwave Coupler

KRYTAR Inc. announces a new 180 degree hybrid coupler that delivers 3 dB of coupling over the broadband frequency range of 1 to 26.5 GHz in a single compact package. Hybrid couplers perform many functions, including splitting and combining signals in amplifiers, switching circuits, and antenna beam-forming networks used in a wide range of commercial and military applications. KRYTAR's new hybrid coupler, model 4010265, delivers this versatility from 1 to 26.5 GHz with excellent phase and amplitude matching. Typical specifications include amplitude imbalance: ±1.0 dB from 1 to 20 GHz and ±1.5 dB from 20 to 26.5 GHz; phase imbalance is ±16 degrees; isolation is >15 dB; maximum VSWR: 1.8 from 1 to 20 GHz and 1.95 from 20 to 26.5 GHz; insertion loss is 3.0 dB from 1 to 20 GHz and 3.6 dB from 20 to 26.5 GHz.

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

Broadband Diode Switches

M/A-COM Tech introduced a family of Heterolithic Microwave Integrated Circuit (HMIC) broadband diode switches that use RoHS compliant Surmount™ packages. These rugged, monolithic switches operate up to 26 GHz, provide low insertion loss and high isolation, and deliver up to +38 dBm CW power handling. The Surmount package technology provides a surface-mount chipscale configuration that is optimized for broadband performance with minimal associated parasitics, which are usually related to hybrid MMIC designs incorporating beam lead and PIN diodes that require chip and wire assembly. These broadband switches are ideally suited for military and test equipment applications.

M/A-COM Technology Solutions Inc.,
Lowell, MA (978) 656-2539,
www.macomtech.com.

Wilkinson Power Dividers

Marki Microwave expands its power divider family with new four-way power dividers. Model PD4-0218 covers 2 to 18 GHz while model PD4-0120 covers 1 to 20 GHz. Both dividers offer outstanding isolation and closely matched port-to-port amplitude and phase balance. These devices are reciprocal units that can be used to split or combine signals.

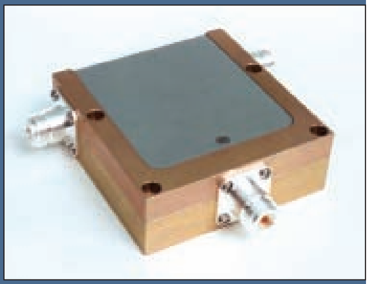
Marki Microwave,
Morgan Hill, CA
(408) 778-4200,
www.markimicrowave.com.

Tuned-by-Design Injector-Diplexer

Microlab introduces a low cost Injector-Diplexer, to separate or combine the new LTE-2600 band (2400 to 2690 MHz) and GSM-850/900

HIGH POWER

100 MHz to 20 GHz

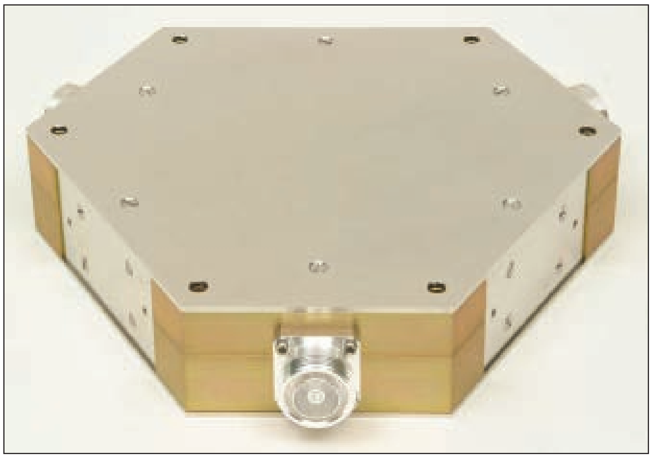


For Military/Radar Applications.

Isolators/Circulators

As one of the leading suppliers of ferrite components in the industry, UTE Microwave has pioneered innovative designs, quality craftsmanship and exceptionally high quality products. Custom designs, standards...many of them off-the-shelf, are the result of over 35 years of experience in the industry. UTE Microwave continues this tradition with new products for ever changing applications. Our broad line of HIGH POWER, low loss circulators and isolators spans the spectrum from below 100 MHz in coax/stripline units to waveguide devices at 18 GHz for both peak and average powers.

100 MHz HIGH POWER Circulator for Medical, Scientific and Industrial applications



A new HIGH POWER Circulator suitable for FM Broadcast, Scientific and Medical applications is now available. The unit provides 10 MHz bandwidth in the 85–110 MHz spectrum.

Specifications are 20 dB min. isolation, 0.3 dB max. loss and 1.25 max. VSWR. Operating power is 1 kW average and 25 kW peak. The 8-1/2" hex x 2" thick unit operates over a 15°–50° C temperature range. DIN 7/16 connectors are standard. Other units are available at higher frequencies.

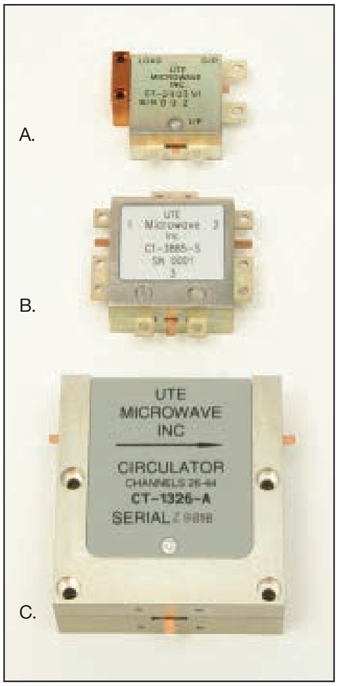
HIGH POWER Drop-in Series

A broad line of low loss HIGH POWER Drop-in circulators are available from VHF to Ku band including Kilowatt average power levels at VHF thru S band. L and S band radar are a specialty. A few of these are shown here.

A) 2.7–3.1 GHZ 1 kW pk, 100 W av

B) 1.2–1.4 GHZ 3 kW pk, 300 W av

C) UHF TV Band 5 kW pk, 500 W av



Our "POWER-LINE" serves the COMMUNICATIONS, TELECOM, MEDICAL, SCIENTIFIC, TV, PCS and INDUSTRIAL markets.

The following models are examples of our High Power units

Model No.	Power	Connectors	Freq. Range
CT-1542-D	10 Kw Pk 1 Kw Av	DIN 7/16	420–470 MHz
CT-2608-S	3 Kw Pk 300 W Av	"Drop-in"	1.2–1.4 GHz
CT-3877-S	2.5 Kw Pk 250 W Av	"Drop-in"	2.7–3.1 GHz
CT-3838-N	5 Kw Pk 500 W Av	N Conn.	2.7–3.1 GHz
CT-1645-N	250 W Satcom	N Conn.	240–320 MHz
CT-1739-D	20 Kw Pk 1 Kw Av	DIN 7/16	128 MHz Medical

FEATURES:

- Power levels to 5 KW CW, 75 KW Pk.
- Low Intermod Units
- Low Loss Options
- Extended Octave Bandwidths
- Power Monitors and DC Blocks
- Iso Filter-Monitor Assemblies

Broadband Units • Common Band Devices • High Isolation Units • Multiport Devices • Drop-In Devices • Wireless/PCN Devices • High-Power Industrial/Medical Iso Adaptors Waveguide Junctions • High-Power TV Units • VHF and UHF Devices

sales@utemicrowave.com

UTE MICROWAVE INC.

3500 Sunset Ave., Asbury Park, NJ 07712
Tel: 732-922-1009 Fax: 732-922-1848
E-mail: info@utemicrowave.com

Contact us for more information on our extensive product line and current catalog. We accept Visa, MC, Amex bands (698 to 960 MHz). Using suspended substrate, the wireless frequency loss is minimized to less than 0.25 dB in all bands. 'Tuned-by-Design' eliminates the high cost of adjusting multiple cavities in conventional designs, while maintaining high 50 dB isolation between key bands, sufficient for most diplexer applications, such as sharing a common antenna or distributed antenna system. Passive InterModulation, PIM, is guaranteed to be <-150 dBc, and guarantees down to -160 dBc are available with an additional testing charge. Units are rated for average powers up to 250 W per input.

Microlab,
Parsippany, NJ (973) 386-9696,
www.microlab.fxr.com.

Tunable YIG Filters

Micro Lambda Wireless announces the production release of bench test YIG-tuned filters that operate in a frequency range from 500 MHz to 50 GHz. Bandpass or band reject models are available. Utilizing the entire Micro Lambda YIG-based tunable filter product line, customers can select from two-, three-, four-, six and seven-stage models in bandpass configurations and from eight-stage all the way through 16-stages for band reject configurations. Bandpass models carry a MLB-FP-series description while the band reject are designated MLBFR-series. Units are specified over the standard lab environment of 0° to +60°C temperature range. Package size is 4" × 10" × 13".

Micro Lambda Wireless Inc.,
Fremont, CA
(510) 770-9221,
www.microlambdawireless.com.

Two-way Power Divider

Pulsar model PS2-55-450/17S covers the frequency range of 1 to 40 GHz with 2.8 dB insertion loss, 10 dB isolation from 1 to 5 GHz and 13 dB from 5 to 40 GHz, and a maximum VSWR of 1.90:1. Amplitude and phase balance are 0.6 dB and ±8 degrees, respectively. Maximum input power is 10 W. 2.92 female connectors are utilized in a housing with dimensions 2.0" × 1.0" × 0.40".

Pulsar Microwave Corp.,
Clifton, NJ (973) 779-6262,
www.pulsarmicrowave.com.

RF Cable Assemblies

The TestPro range has been extended with the introduction of TestPro 3 RF cable assemblies that are precision engineered with advanced materials and are designed for extreme stability and flexibility. The cables have been tested for bending stability according to IEC 966-1, bending method number 2. Results show good phase stability as low as 5° typical with bending at 40 GHz. To meet the requirements for stability with handling during bench test use, the cables also offer loss stability of less than 0.1 dB variation with bending and 0.03 dB with shaking at the maximum frequency of 40 GHz. In addition, the cable and connectors are designed for long life, rated for a minimum of 20,000 bending cycles and 5,000 mating cycles.

Radiall USA Inc.,
Chandler, AZ (480) 682-9400,
www.radiall.com.

Precision SMA Adapters

Test grade adapters need to be rugged and versatile for use in lab or field applications. To meet this increasing need, RF Precision Products has released a complete line of the most popular test adapters covering SMA and N-types. Precision machined passivated stainless steel construction for long life, repeated use and corrosion resistance. All adapters feature epoxy captivated components and are designed for outstanding electrical performance with low loss and guaranteed low VSWR to 18 GHz. N to SMA adapters are suitable for use with the Anritsu Site Master™ line of test equipment and other similar popular brands.

RF Industries,
San Diego, CA (858) 549-6340,
www.rfindustries.com.

Single and Dual Directional Couplers

RLC Electronics' high power directional couplers offer accurate coupling, low insertion loss and high directivity in a compact package. The

standard units are optimized for two octave bandwidths and are available with a choice of coupling values. These units are ideal for sampling forward and reflected power with a negligible effect on the transmission line and very low intermodulation products.

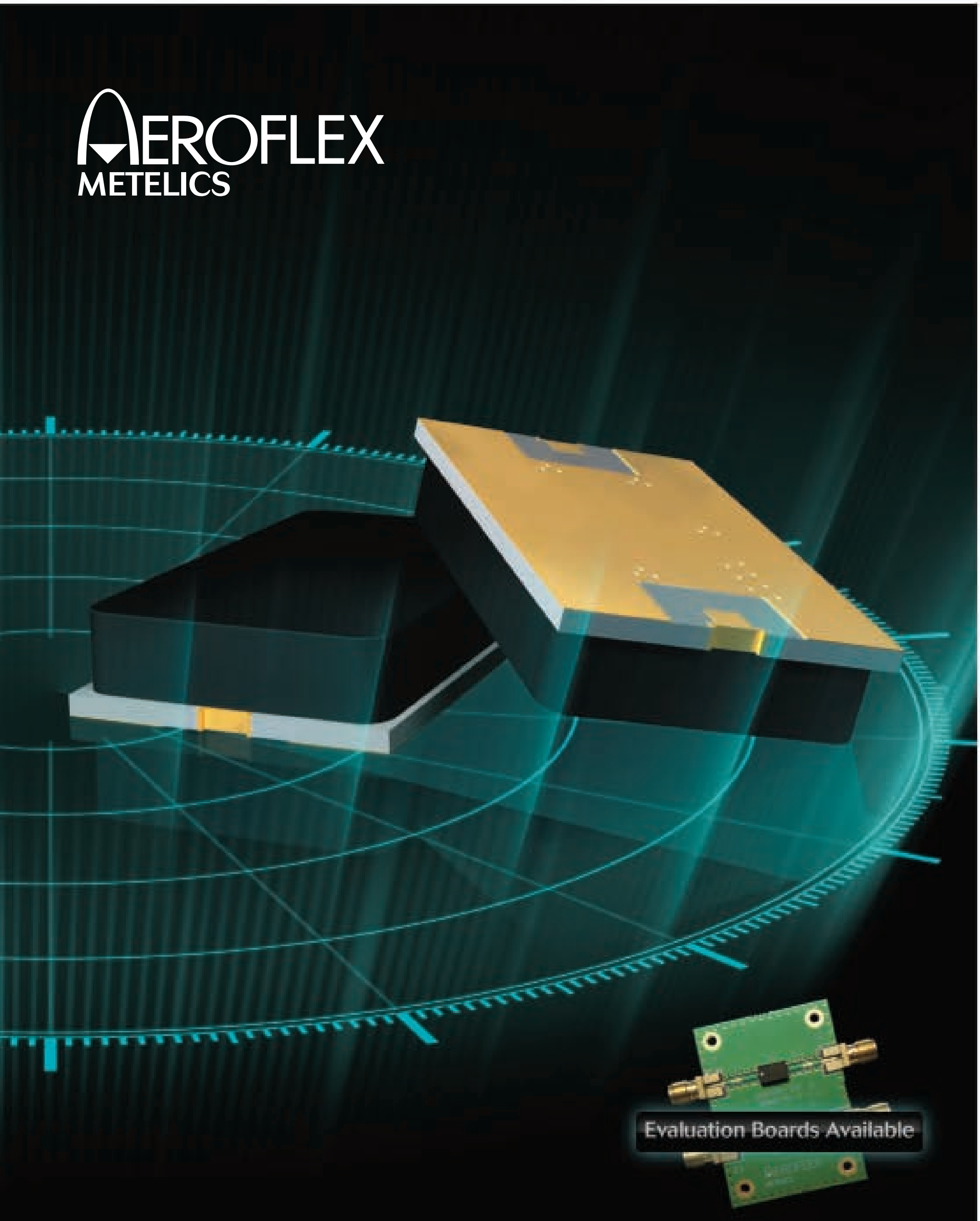
RLC Electronics Inc.,
Mount Kisco, NY (914) 241-1334,
www.rlcelectronics.com.

Amplifiers

Dual Output Amplifier

Model AML618P5012 is a high efficiency dual (combined) input, dual output power amplifier operating over 6 to 18 GHz bandwidth. The amplifier delivers +31 dBm power at each output and is designed to operate up to +95°C base

Protecting your radar system just got a whole lot easier



New high power surface mount limiters from Aeroflex / Metelics are making your receiver/ protector sections a whole lot easier to design. These drop-in devices include 11 completely integrated components that have been optimized for S and C band radar systems. In comparison to silicon and GaAs MMICs, which lack thermal capacity and thermal conductivity, these devices offer stable peak power handling through 8 GHz.

- **Frequency bands from 20 to 8000 MHz**
- **100 W C.W. and 1 KW Peak Power Handling**
- **Flat Leakage Power of 20 dBm**
- **8 x 5 x 2.5 mm SMT Packaging**

We've put our semiconductor experience to work in developing a variety of broadband and octave band models. Call or visit our website for details.

603-641-3800

www.aeroflex.com/metelicsMJ

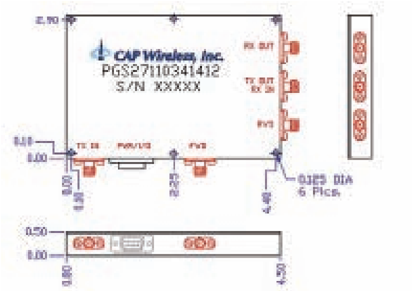
High Power Surface Mount Limiters

Part Number	Type	Frequency (MHz)*	Loss (dB)	C.W. Power (W)
LM200802-M-A-300	Medium Power Broadband	20-8000	1.4	20
LM501202-L-C-300	Octave Band, Low Power	500-2000	0.4	4
LM501202-M-C-300	Octave Band, Med Power	500-2000	0.6	30
LM202802-L-C-300	Octave Band, Low Power	2000-8000	1.0	4
LM202802-M-C-300	Octave Band, Med Power	2000-8000	1.2	30
LM401102-Q-C-301	Octave Band, High Power, "Quasi-Active"	400-1000	0.3	100
LM102202-Q-C-301	Octave Band, High Power, "Quasi-Active"	1000-2000	0.5	100
LM202802-Q-C-301	Octave Band, High Power, "Quasi-Active"	2000-8000	1.4	100

AEROFLEX
A passion for performance.

plate temperature. AML-618P5012 is available with input power protection option up to 2 W CW. This design is available in a high-density package with 3.5"L × 1"W × 0.3"H. RF connectors are SMP. The DC supply is +10 V at 2.2 Amps.
AML Communications Inc.,
Camarillo, CA (805) 388-1345,
www.amlj.com.

Broadband Power Amplifier



The PGS27110341412 broadband power amplifier employs GaN technology to provide 12 W of saturated power from 27 to 1000 MHz. This high efficiency amplifier finds applications in communications, jamming, as well as test and measurement. Operational from a wide range 24 to 32 V DC supply, it incorporates features including blanking, forward and reverse sampling couplers, and an integrated receive path and T/R switch.
CAP Wireless,
Newbury Park, CA (805) 499-1818,
www.capwireless.com.

Power Amplifier
VENDORVIEW

This 900 MHz compact linear power amplifier is the first in a series of communications amplifiers that are being developed for digital waveform requirements in the 450, 700, 800, 900, 1800, 1900 and 2100 MHz bands. The 7091 and this family of emerging products are well suited for use in commercial LTE networks and public safety wireless communications applications. The 7091 amplifier employs latest generation LDMOS device technology and is highly efficient. The amplifier has an advanced, built-in predistortion engine with wide instantaneous correction bandwidth, which ensures low distortion and wide dynamic range operation.
Empower RF Systems Inc.,
Inglewood, CA
(310) 412-8100,
www.empowerrf.com.

LDMOS Power Transistors
VENDORVIEW

Freescale Semiconductor unveiled three advanced industrial RF power transistors at an ideal price/performance ratio for original equipment manufacturers (OEM). The enhanced rugged capability combined with leading-edge RF performance enables OEMs to realize significant cost savings at the system level for industrial and commercial aerospace designs. Freescale's MRFE6VP5600H/S and MRFE6VP61K25H/S 50 V LDMOS power transistors offer enhanced ruggedness to support harsh environments in highly mismatched applications such as plasma generators, CO2 lasers and MRI power amplifiers. The MRF8P29300H/S 30 V LDMOS power transistor is designed for pulsed S-band applications such as air traffic control (ATC) and also can support modulated communications applications.
Freescale Semiconductor,
Austin, TX
(800) 521-6274,
www.freescale.com.

Coaxial High Power Amplifier
VENDORVIEW

The Mini-Circuits ZHL-100W-GAN+ utilizes high power Gallium Nitride (GaN) output stage, which results in higher efficiency (50 percent typical) as compared to GaAs, LDMOS and VDMOS counterparts. This high power amplifier operates in a frequency range from 20 to 500 MHz and features high output power, 100 W; GaN output stage; high output IP2, +84 dBm typical and high output IP3, +60 dBm typical. GaN FETs boast a maximum junction temperature of 250°C translating into higher operating temperatures without adversely affecting the MTBF. Feature advantages include: high efficiency - higher PAE results in significant cost savings over the operating life of amplifier; rugged design - extreme load mismatch such as open/short at output are tolerated without damaging the amplifiers; and range of protections - over temperature, over voltage and reverse polarity protection add to the ruggedness of the amplifier.

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

Low Noise Amplifier
VENDORVIEW

MITEQ Inc. introduces a new addition to its family of K-band waveguide LNAs. Model JDM2WK-18002600-25-10P is a very low noise, high dynamic range waveguide front-end with WR-28 waveguide input and K(F) connector output. Additional options include pressure windows and three flange configurations, choke, grooved and cover. The JDM2WK-18002600-25-10P is lightweight and has a small profile and footprint. The aluminum alloy housing is environmentally sealed and also fully EMI shielded. The LNA includes reverse voltage protection and full internal regulation. Total weight is approximately 32 grams, and di-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HYBRIX3
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is added to our collection

mensions are 58.12 × 22.35 × 22.35 mm.
MITEQ Inc.,
Hauppauge, NY (631) 436-7400,
www.miteq.com.

Low Noise Amplifier

PMI amplifier model PEC-42-1G40G-20-12-292MM is an ultra-broadband low noise amplifier that operates in a frequency range from 1 to 40 GHz. This model provides a flat gain response while maintaining a typical output power of +20 dBm. Key specifications include operating frequency: 1 to 40 GHz; gain: +42 dB; gain flatness: ±2.5 dB; noise figure: 4.6 dB at 12 GHz; OP1dB: +22 dBm (1 to 18 GHz), +19 dBm (18 to 40 GHz); power supply: Single +12 VDC; connectors: 2.92 mm. Size: 1.37" × 1.0" × 0.6".
Planar Monolithics Industries,
Frederick, MD
(301) 662-5019,
www.pmi-rf.com.

Material

High-thermal-conductivity Laminate

VENDORVIEW

Rogers Corp. has introduced RT/duroid® 6035HTC, a new high-thermal-conductivity (HTC) laminate material engineered for low loss in high-power circuits. The fluoropolymer

composite material is ideal for RF and microwave applications in military and high-reliability (hi-rel) applications required to handle high power levels, such as power amplifiers. Rogers RT/duroid 6035HTC laminates feature a relative dielectric constant of 3.5 at 10 GHz, making them suitable for a wide range of circuits employed in avionic and other military and hi-rel systems. The laminates incorporate a unique filler material to achieve superior heat-transfer characteristics compared to other high frequency circuit materials with similar dielectric constant.
Rogers Corp.,
Chandler, AZ (480) 961-1382,
www.rogerscorp.com.

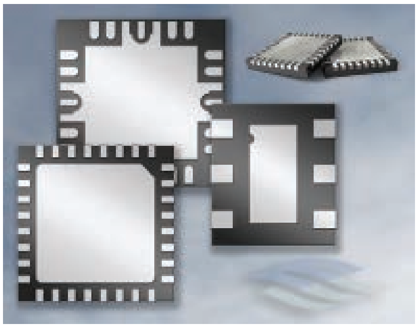
Semiconductors/ Integrated Circuits

Highly Integrated Demodulator

ADI introduced a new highly integrated demodulator for broadband applications, such as cellular base stations, satellite communications, point-to-point (PtP) radios and defense systems. ADI's new ADRF6850 demodulator expands ADI's RF/microwave product portfolio and offers the highest level of integration and functionality by combining five devices and three RF functions into one small-footprint, surface-mount chip. ADI's single-chip ADRF6850 demodulator saves considerable board space, reduces cost, and simplifies development by integrating a 60 dB VGA, a fractional-N PLL synthesizer with VCO and two baseband ADC drivers all in an 8 × 8 mm LFCSP package.
Analog Devices Inc.,
Norwood, MA (781) 329-4700,
www.analog.com.

QFN Packages to 50 GHz

VENDORVIEW



Endwave has an advantage when housing its high-performance monolithic-microwave-integrated-circuit (MMIC) products in a surface-mount package. By re-engineering the widely accepted QFN, or Quad Flat No-leads surface-mount-technology (SMT) package, Endwave has more than doubled the usable frequency range of the housing, increasing its upper-frequency limit to 50 GHz and higher. A standard QFN package is a micro-lead-frame-type surface-mount-technology (SMT) housing designed to provide protection for MMICs and other semiconductors while also simplifying their attachment to printed-circuit boards (PCB). By their design, QFNs allow solder connections directly to PCB traces, without the complexity of fabricating plated through holes (PTH) in the circuit board. Standard lower-cost plastic-molded QFN packages operate to about 3 GHz, while conventional higher-performance air-cavity QFNs can be used to about 25 GHz.
Endwave Corp.,
San Jose, CA
(408) 522-3100,
www.endwave.com.

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Software

EM Simulation Software
VENDORVIEW

Remcom announces an updated version of XFdtd® Release 7 (XF7), containing new functionality to shorten simulation setup time and output analysis. Notable enhancements include additional GPU acceleration for XACT Accurate Cell Technology and for plane wave simulations. Comprehensive improvements extend performance and usability, increasing throughput before and after the simulation: XACT Accurate Cell Technology mesh calculations have been accelerated up to 15 times; XStream® now supports NVIDIA's Fermi architecture, the most advanced CUDA-enabled GPU technology available; Arbitrary cut-planes facilitate interaction with complex models. These cut-planes are tightly integrated with XF7's advanced 2D Sketcher, allowing snapping and measuring of cut geometry.

Remcom Inc.,
State College, PA (814) 861-1299,
www.remcom.com.

Sources

Voltage-controlled Oscillator

Crystek's CVCO55CC-3475-3475 voltage-controlled oscillator (VCO) operates at 3475

MHz with a control voltage range of 0.5 to 4.5 V. This VCO features a typical phase noise of -115 dBc/Hz at 10 kHz offset and has excellent linearity. Output power is typically +7 dBm. Engineered and manufactured in the USA, the model CVCO55CC-3475-3475 is packaged in the industry-standard 0.5" × 0.5" SMD package. Input voltage is 8 V, with a maximum current consumption of 35 mA.

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

250 MHz Phase-locked Crystal Oscillator

The PLXO-250 phase-locked crystal oscillator operates at 250 MHz in a miniature connectorized package (1.5" sq × 0.6"). Featuring low spurs (-70 dBc), extremely-low harmonics (-50 dBc) and sub-harmonics (-70 dBc), the unit is locked to a 10 MHz external reference (or optional internal reference), and exhibits exceptionally-low phase noise (-120 dBc/Hz at 1 KHz), +7 dBm output power (maximum), while operating on a supply voltage of +12 VDC. The PLXO-250 is ideal for use with A/D and D/A converters, GPS carrier recovery loops or as reference sources for Ka-band and mm-Wave frequency converters, and various test equipment.

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

Voltage-controlled Oscillator

The model V500ME03-LF is a RoHS compliant voltage-controlled oscillator (VCO) in

UHF-band. The V500ME03-LF operates at 500 to 1000 MHz with a tuning voltage range of 0 to 11 VDC. This VCO features a typical phase noise of -105 dBc/Hz at 10 kHz offset and a typical tuning sensitivity of 54 MHz/V. The V500ME03-LF is designed to deliver a typical output power of 10 dBm at 12 VDC supply while drawing 25 mA (typical) over the temperature range of -40° to 85°C. This VCO features typical second harmonic suppression of -13 dBc and comes in Z-Comm's standard MINI-16-SM package measuring 0.5" × 0.5" × 0.22".

Z-Communications Inc.,
San Diego, CA (858) 621-2700,
www.zcomm.com.

Subsystem

Radio Link RF Subsystem

DTI has announced the release of E-band Radio link RF subsystem. This subsystem operates over the E-band frequency spectrum from 71 to 86 GHz. One of its applications can be found in the E-band multi-gigabit wireless communication system, which offers local area networks and "Virtual Fiber" local loop for wireless transmission of data, voice and video at 1 to 10 Gbps speed. DTI's E-band radio link RF subsystem includes two transceiver blocks. The block A transmits at the frequency of 71 to 76 GHz and receives at 81 to 86 GHz, while the block B works at the opposite frequency ranges. Each block has transmitter (TX), receiver (RX), local oscillator (LO) chain and phase locked dielectric resonator oscillator (PLDRO) modules.

Ducommun Technologies Inc.,
Carson, CA (310) 847-2859,
www.ducommun.com.

2011 Microwave Industry Exhibition in China (MIE 2011)

2011 National Conference on Microwave and Millimeter Wave in China

MIE 2011

For detail information, Please visit www.cnmw.org www.mws-cie.org

Sponsors: Chinese Institute of Electronics (CIE)

Co-sponsors:
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China University of Petroleum

Collaborating journals:
Journal of Microwaves(Chinese)
Chinese Journal of Radio Science
Mobile Communications(Chinese)
Microwave Journal(English)
Rfeda, Mrfn, Eefocus, Kilomega and Wbsp.

Conference / Exhibition Date: June 4 - 7, 2011 **Conference / Exhibition Venue:** Qingdao, P.R. China

Microwave Industry Exhibition has been held for over 10 years. It is held every year, with the National Conference on Microwave and Millimeter Wave in China (Microwave Annual Conference of China) every odd year and with the International Conference on Microwave and Millimeter Wave Technology every dual year.
MIE 2011 will be another grand exhibition after MIE 2010 in Chengdu, MIE 2009 in Xi'an, MIE 2008 in Nanjing China!

Exhibitors to be attended:

- Fabricator / distributor for RF / microwave / millimeter wave devices / components: solid state device and circuits (including MMIC): amplifiers, mixers, oscillators, etc. and passive components: filters, duplexers, couplers, attenuators, and antennas etc.
- Designer / distributor for RF / microwave / millimeter wave software.
- Fabricator / distributor for RF / microwave / millimeter wave equipments.
- Fabricator / distributor for RF / microwave PCB and connectors.
- Fabricator / distributor for microwave absorber.
- Fabricator / distributor for microwave / millimeter inductor, capacitor and high power resistor.
- RF / microwave / millimeter related press and media.

Why you should attend?

- MIE 2011 is the largest event of microwave field in China, which is sponsored by Chinese Institute of Electronics(CIE).
- MIE 2011 is where to provide a platform for enterprises engaged in Microwave Millimeter wave and RF field to publicize your company/ products in China.
- MIE 2011 will provide a chromatic company introduction page (210mm×285mm) for each exhibitor in List of Exhibitors, which is free.
- MIE 2011 is where to provide a nice opportunity for the scientists and engineers specialized in Microwave and Millimeter wave field to present your new ideas and learn from each other.

There are two kinds of booths: Standard booth and Customized booth:
Standard booth: 3 m x 3 m,
Consist of one headboard with company name (limited in 30 characters), one table, two chairs and so on.
Customized booth: From 36 m²
Empty area, you can customize the booth to highlight your company / products.

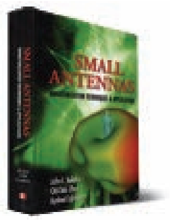
Background of National Conference on Microwave and Millimeter Wave in China (NCMMW)

NCMMW is China's largest conference on microwave and millimeter wave technologies. It is Sponsored by Chinese Institute of Electronics (CIE) and held every two years (every odd year).

NCMMW 2011 will be held in Qingdao International Conference and Exhibition Center, P.R. China, on June 4-7, 2011(Decoration June 4), The proceedings of the conference will be published by Publishing House of Electronics Industry of China.

NCMMW 2011 will surely attract a large number of scholars and industry companies of China Mainland, Hong Kong, Macao and Taiwan. It is a great opportunity for publicizing your company / products.

Contact: Mr. Wei, Ms Xu
Tel: 86-755-83655339, Fax: 86-755-83629073
Email: mwrf@vip.163.com kingradio@163.net
www.cnmw.org www.mws-cie.org/ncmmw2011



Small Antennas: Miniaturization Techniques & Applications

John Volakis, Chi-Chih Chen and Kyohei Fujimoto

Small Antennas: Miniaturization Techniques & Applications provides up-to-date methods on the theory and design of small antennas, including an extensive survey of small antenna literature published over the past several years. Antennas have always been difficult to miniaturize, but recent developments in novel materials, either natural or synthetic (metamaterials), and a variety of synthesized anisotropic media are changing the landscape.

This book aims to provide the reader with a single stop on small antennas, including: theory and applications, performance limits subject to bandwidth, gain and size; narrowband and wideband; conformal and integrated; passive and negative (non-foster) impedance matching; materials (polymers, ceramics and magnetics) and shape optimization; high impedance, artificially magnetic and electromagnetic bandgap (EBG) ground planes; techniques for miniaturizing narrowband and wideband antennas; metamaterial and photonic crystal antennas, RFID and power harvesting rectennas; and a multitude of real-world applications that represent an extensive literature survey over the past few years.

The text begins with a detailed presentation of small antenna theory—narrowband and wideband—and progresses to small antenna design methods, such as materials and shaping approaches for multiband and wideband antennas. Generic miniaturization techniques are presented for narrowband, multiband and wideband antennas. Two chapters devoted to metamaterials antennas and methods to achieve optimal small antennas, as well as a chapter on RFID technologies and related antennas are also included.

This comprehensive book on antenna miniaturization is very timely as today's antenna is quickly changing with all the demands on improved efficiency and compact size for mobile applications. The novel materials and newer design techniques are useful for the engineer and student who have a background in antenna design. The future of antenna design is rapidly changing and this book will help designers with its modern examples and coverage of new techniques, materials and packaging technology.

To order this book, contact:

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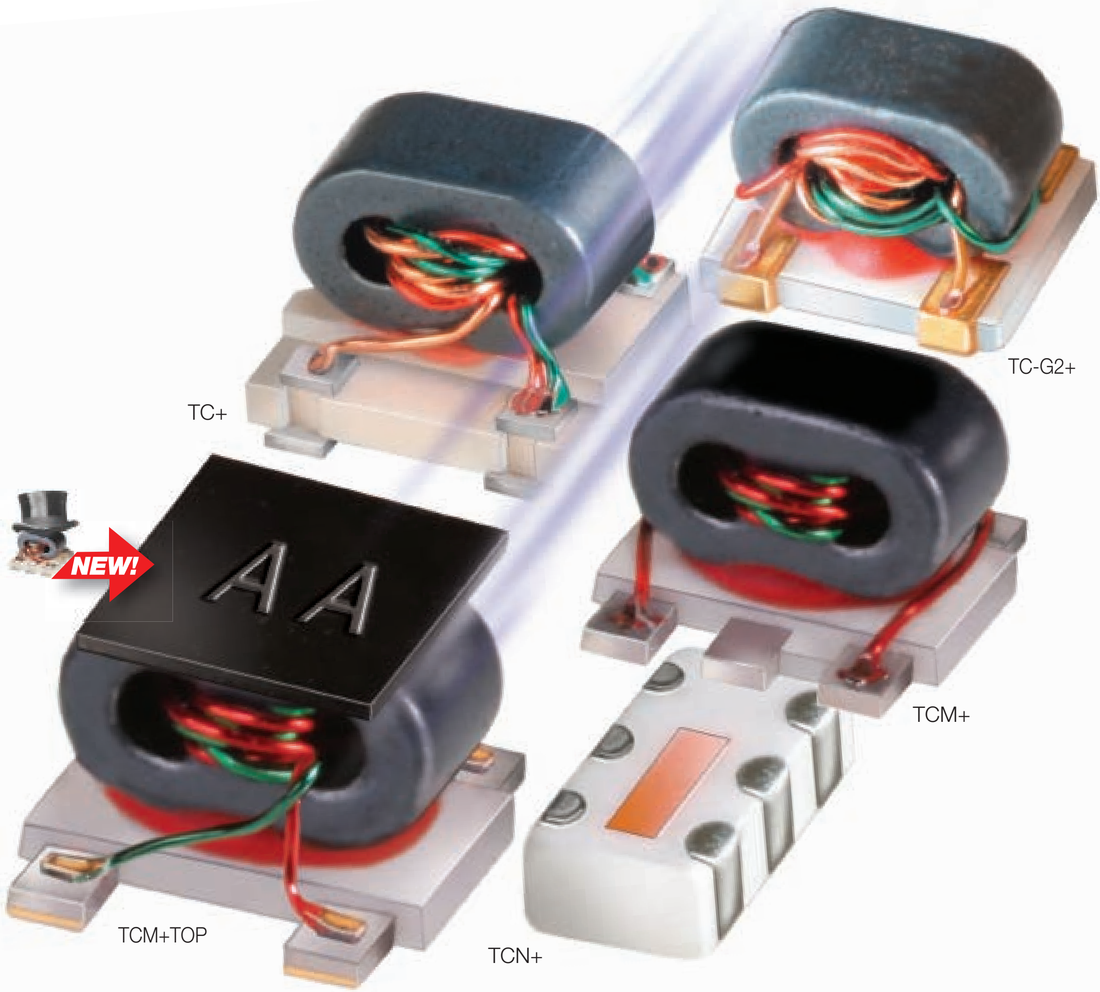

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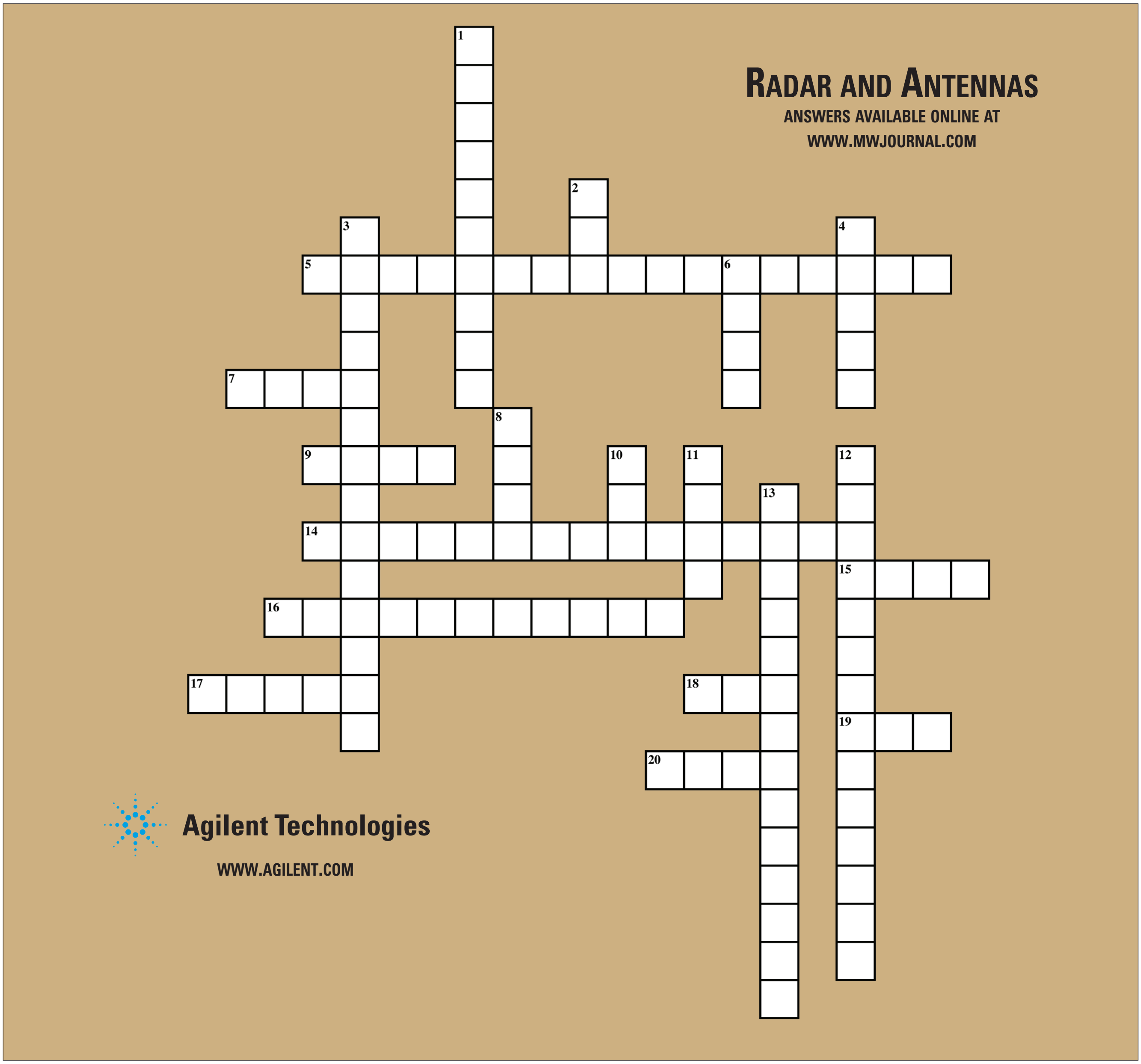

ACROSS

5 LTE (3 words)
7 Hybridization of FEM and IE solvers
9 Short for multi-input, multi-output
14 MoM (3 words)
15 Short for signal-to-interference-plus-noise-ratio
16 A signal processing technique used in sensor arrays for directional signal transmission or reception
17 3G standard that most GSM carriers use
18 Power added efficiency
19 Perfectly matched layer
20 Short for digital arbitrary waveform generator

DOWN

1 90° out of phase
2 Global System for Mobile Communications
3 Term for the next generation of adaptive radar that has transmit-receive adaptivity and diversity, along with "intelligent" high performance embedded computing (2 words)
4 Currently the mostly widely deployed 4G standard
6 Low temperature co-fired ceramic
8 Finite difference time domain
10 Finite element method
11 Microelectromechanical systems
12 DARPA program called Knowledge-Aided Processing for Enhanced Real-Time Adaptivity (2 words)
13 KA (2 words)

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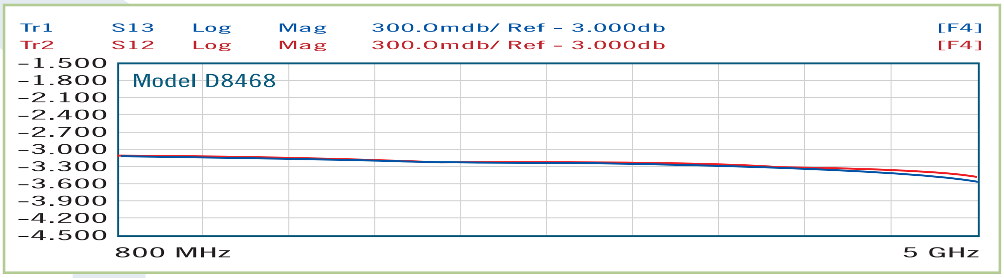
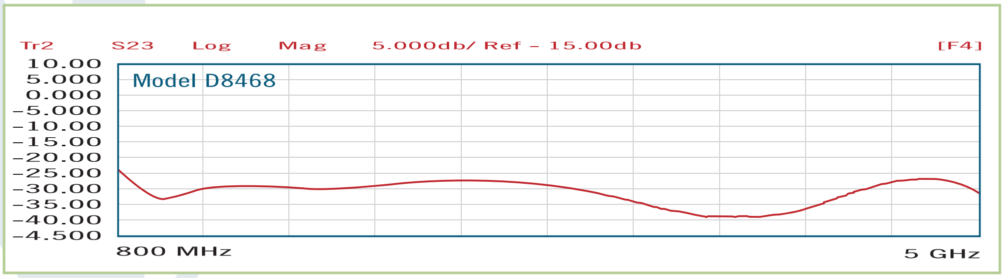
Insertion Loss



Isolation



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Model	Type	Frequency (MHz)	Power (W CW)	Insertion Loss (dB)	VSWR	Isolation (dB)	Size (Inches)
D7885	2-Way	200-2500	200	0.65	1.40:1	15	7.7 x 1.6 x 1.1
D8611	2-Way	400-3000	200	0.6	1.35:1	15	4.7 x 2.0 x 0.8
D7823	2-Way	500-2500	200	0.4	1.35:1	15	4.7 x 2.0 x 0.8
D8414	2-Way	600-3000	200	0.5	1:35:1	15	4.0 x 1.9 x 1.0
D8378	2-Way	500-2000	800	0.4	1:35:1	15	4.0 x 1.9 x 1.37
D8468	2-Way	800-5000	150	0.6	1:35:1	15	3.4 x 1.4 x 0.87
D8294	2-Way	1000-4000	100	0.5	1:30:1	15	3.7 x 1.9 x 0.87

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