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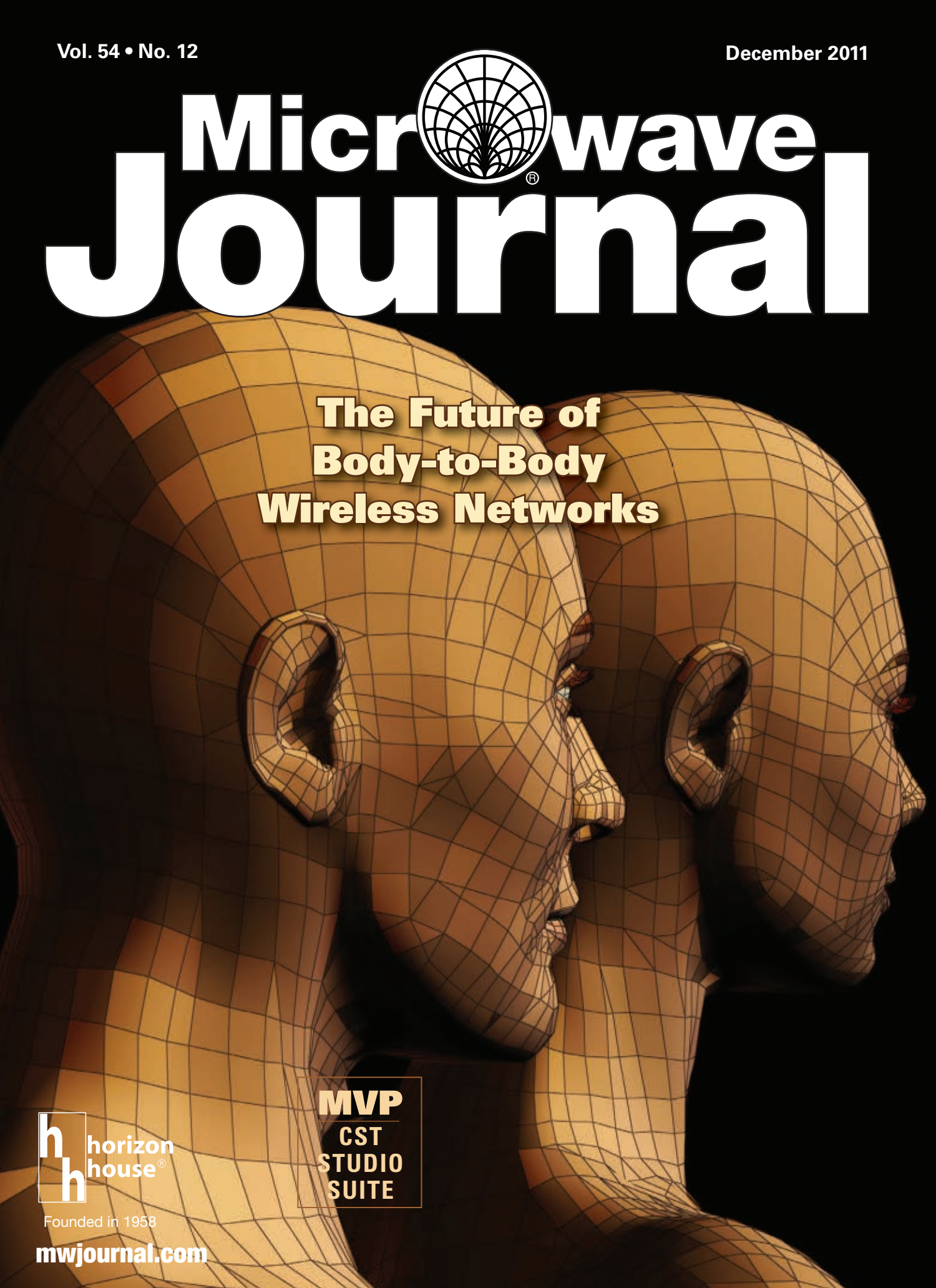
December 2011

Microwave Journal



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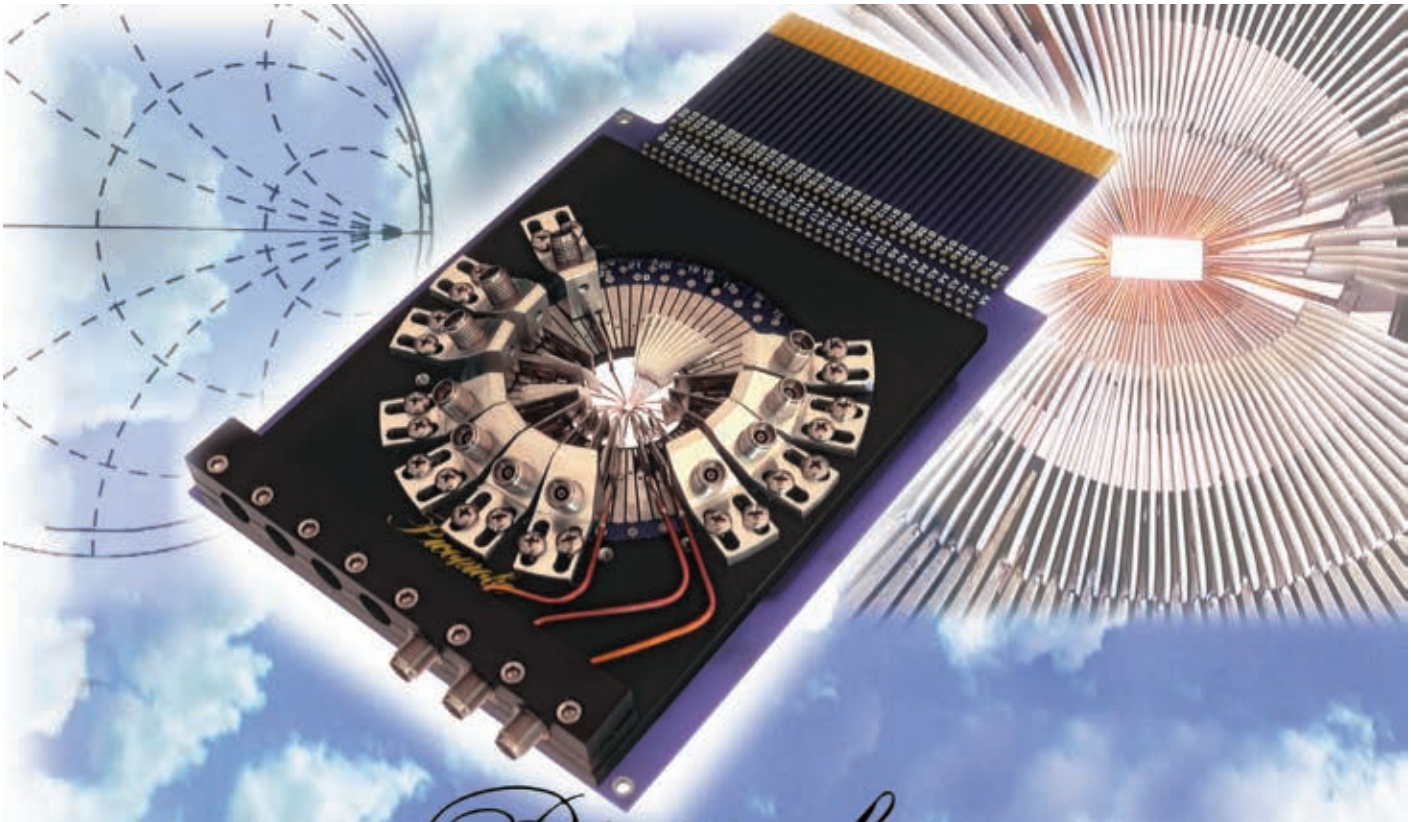

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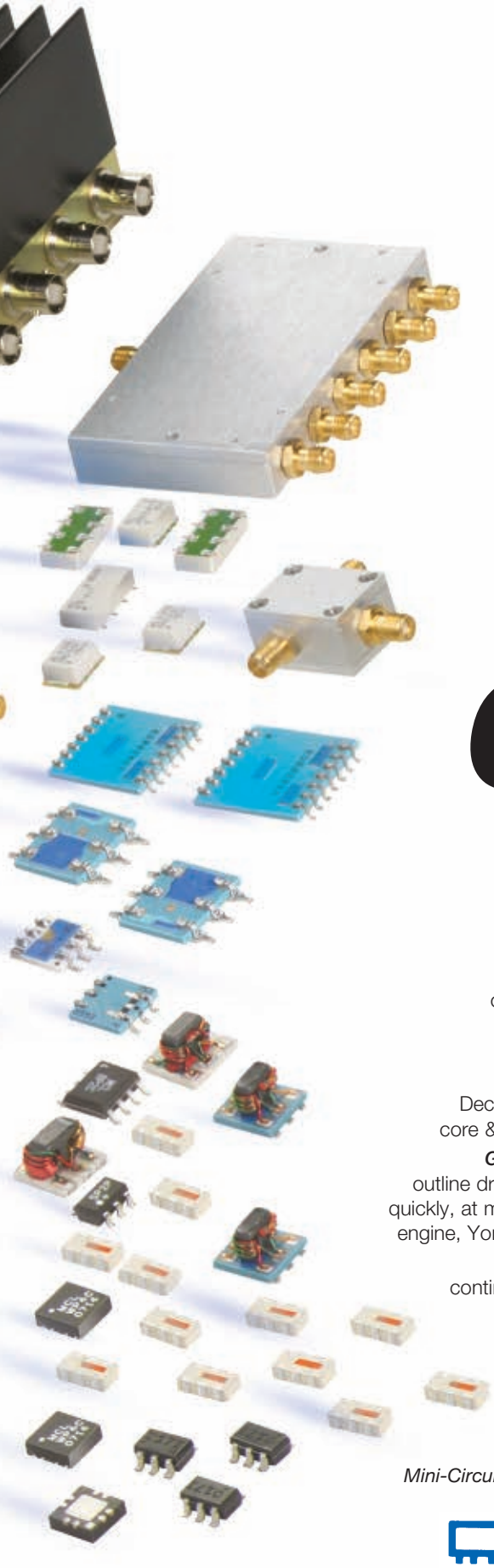

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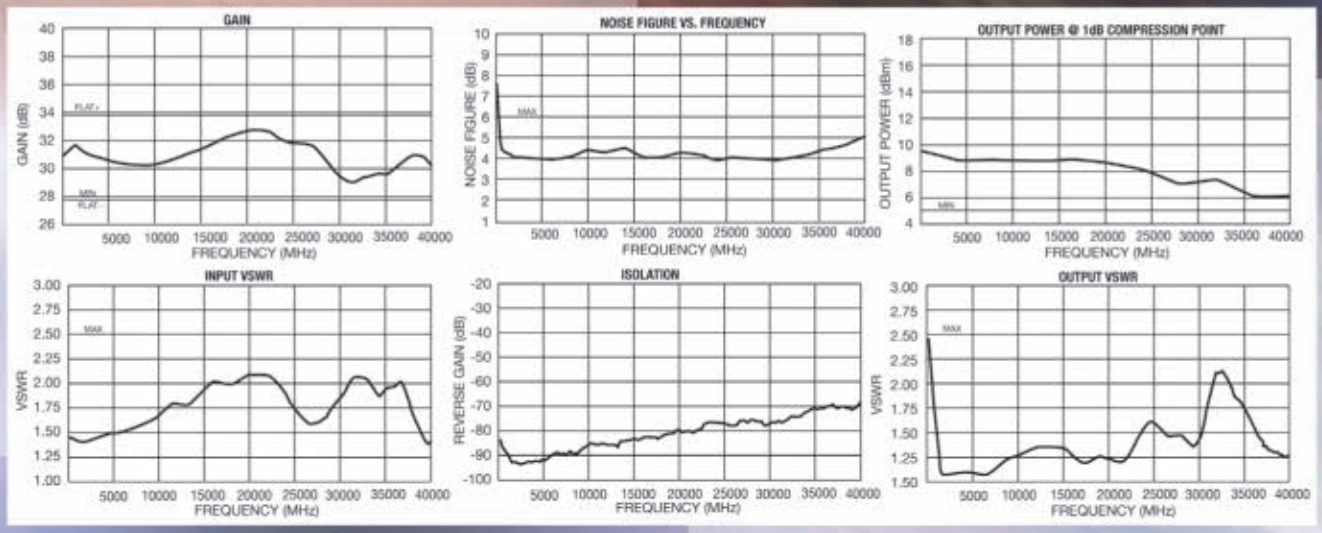

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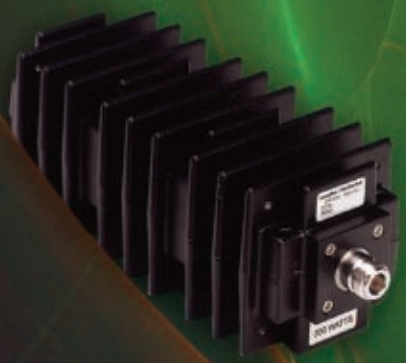

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Erratum: In last month's Technical Feature, "A Compact Dual-Wideband Bandpass Filter Using Spiral-Shaped Multi-Mode and Complementary Split Ring Resonators," one of the author's names is misspelled. The correct name is Mojgan Daneshmand, University of Alberta.

STAFF

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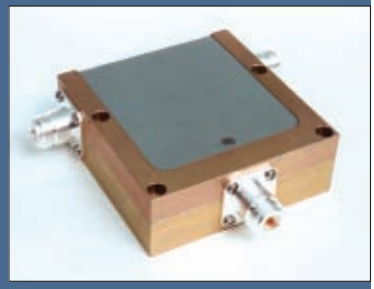

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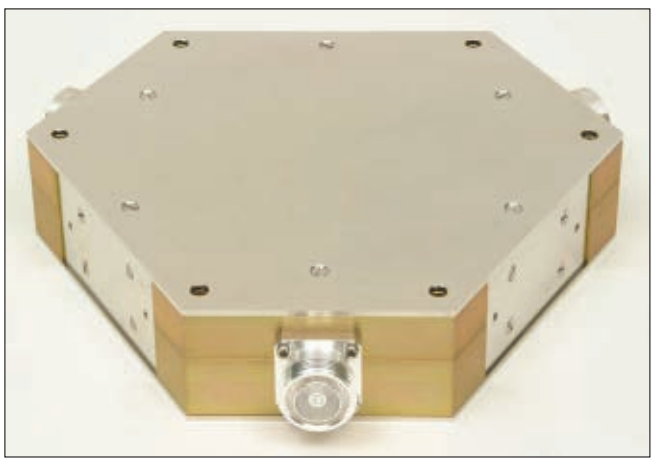

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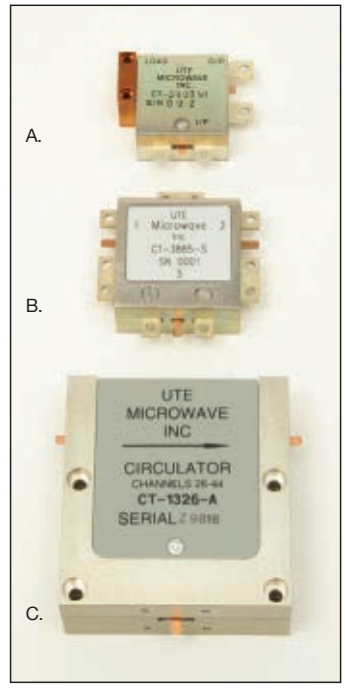

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CT-3838-N	5 Kw Pk 500 W Av	N Conn.	2.7–3.1 GHz
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Executive Interview

Peter Real, Vice President of Analog Devices' Linear and RF group, discusses the company's new products and how Analog Devices opened up its laboratory expertise with the "Circuits from the Lab" series.

Online Technical Papers

AWR's Visual System Simulator Co-Simulates with NI's LabVIEW for Enhanced Signal Processing Capabilities
Gent Paparisto, AWR Corp.

Integrated LNA Serves Base Station Needs
Chin-Leong Lim, Avago Technologies

Comparative Study of an Open Waveguide. Application to Deconvolution of a Magnetic Probe in Near-Field Zone
Presented by COMSOL

Accurate Co-Simulation of Surface-Mount Capacitors in Shunt Configurations
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Bandwidth vs. Efficiency Trades in RF Amplifier Design
Greg Ramon, QinetiQ North America

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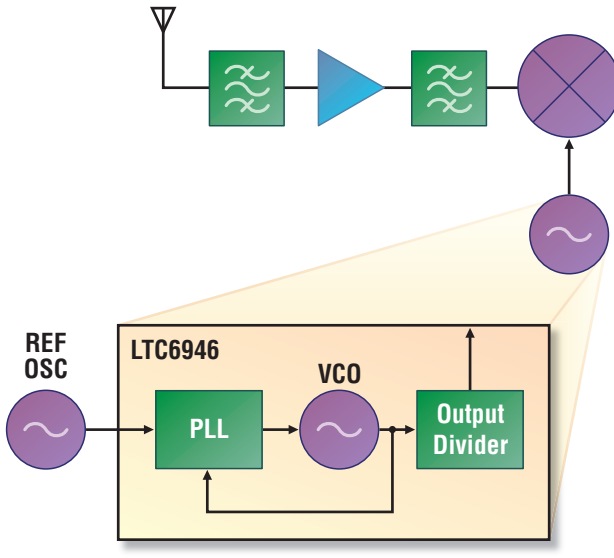

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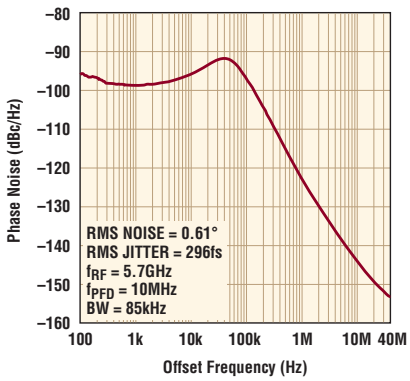

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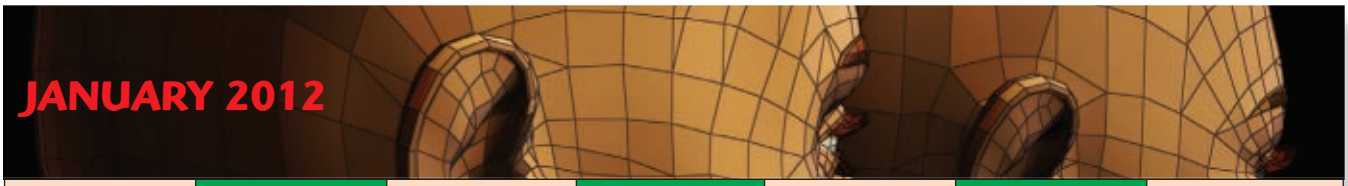

JANUARY 2012

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
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22	23	24	25 Webinar: Innovations in VSA Agilent Technologies	26 Webinar: Innovations in LTE Agilent Technologies	27	28
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THE YEAR THAT WAS...

DAVID VYE, *MICROWAVE JOURNAL* EDITOR

My hometown of Newburyport is located by the ocean at the mouth of the Merrimac River in the upper eastern corner of Massachusetts. Exploiting its natural resources, the first settlers were naturally fisherman. As larger and more commercially successful fishing communities took root in Gloucester and New Bedford, the city transitioned into a ship-building hub, designing and manufacturing the fast clipper ships needed to rapidly transport tea from China and the East Indies to Britain and the world in the 19th century.

Then, as now, being first to market was essential to business success. And so, trade merchants needed faster, more efficient commercial vessels capable of a global reach, all design features of the Newburyport Clipper ships. But eventually, the ship building business migrated to larger labor markets, such as Portsmouth, Boston, New York and beyond. With little land to farm, many inhabitants parlayed their knowledge of building and working on trade ships into careers as merchants and traders. Today, many of the city's residents carry on the global merchant tradition as business people seeking opportunities around the world.

I keep this history in mind when considering our own industry's need to evolve and seek opportunities wherever they might be located. The global economy is not a new concept. Many microwave companies have been building their off-shore business for years. What is new is the introduction of a unified microwave industry marketing channel under the Microwave Journal brand, specifically for companies doing business in China.

In November, we announced the launch of Microwave Journal China, a bi-monthly magazine in simplified Chinese available in print and electronically. It will provide this market with articles and product information from international companies as well as local interest news and events. Publisher Carl Sheffres and I travelled to the 6th Annual International Microwave and Antenna Exhibition (IME 2012) in Shanghai to promote the new publication with a 20-page preview magazine. The response from Chinese engineers and international companies in attendance was overwhelmingly positive.

With tens of millions of new cellular subscribers in China each year, utilizing networks that operate from 2G to 4G, the demand for hardware is immense and the technical challenges are not trivial. In short, this is a market looking to be served. But it is also one that has its fair share of business obstacles and pitfalls. With a dedicated Microwave Journal China media outlet, we hope to significantly reduce communication barriers between supplier and engineer. As an industry, I believe we can leverage our combined strength to open up new opportunities for all. We always have in the past.

Of course, connecting technology companies to end-users is a concern throughout the industry and we saw some interesting trends in 2011. I am pleased that most microwave companies recognized the value of technical content and choose to market their products through a constructive technical discussion with their prospective customers. This conversation took many forms in 2011. On the editorial side, we experienced a healthy uptick in companies willing to submit articles detailing their technological advances.

This editorial influx was in addition to the steady stream of product features, new product announcements and tech briefs we frequently receive. We also published 50 online exclusive white papers this year. Less prolific writers still managed to stay in front of their intended audience with meaningful print advertising. I applaud everyone who produced ads that caught readers' attention while educating them. Never underestimate how much the industry stays informed by gazing at ads while thumbing through Microwave Journal.

Connecting at an even higher level requires a conversation between presenter and audience. This past year, we saw an increase in microwave companies exploring new ways to hold conversations with their customers. For instance, the number of webinars with question and answer sessions doubled in 2011 over the previous year. This format was not restricted to webinars. This year, Microwave Journal organized expert forums on non-

(Continued on page 22)

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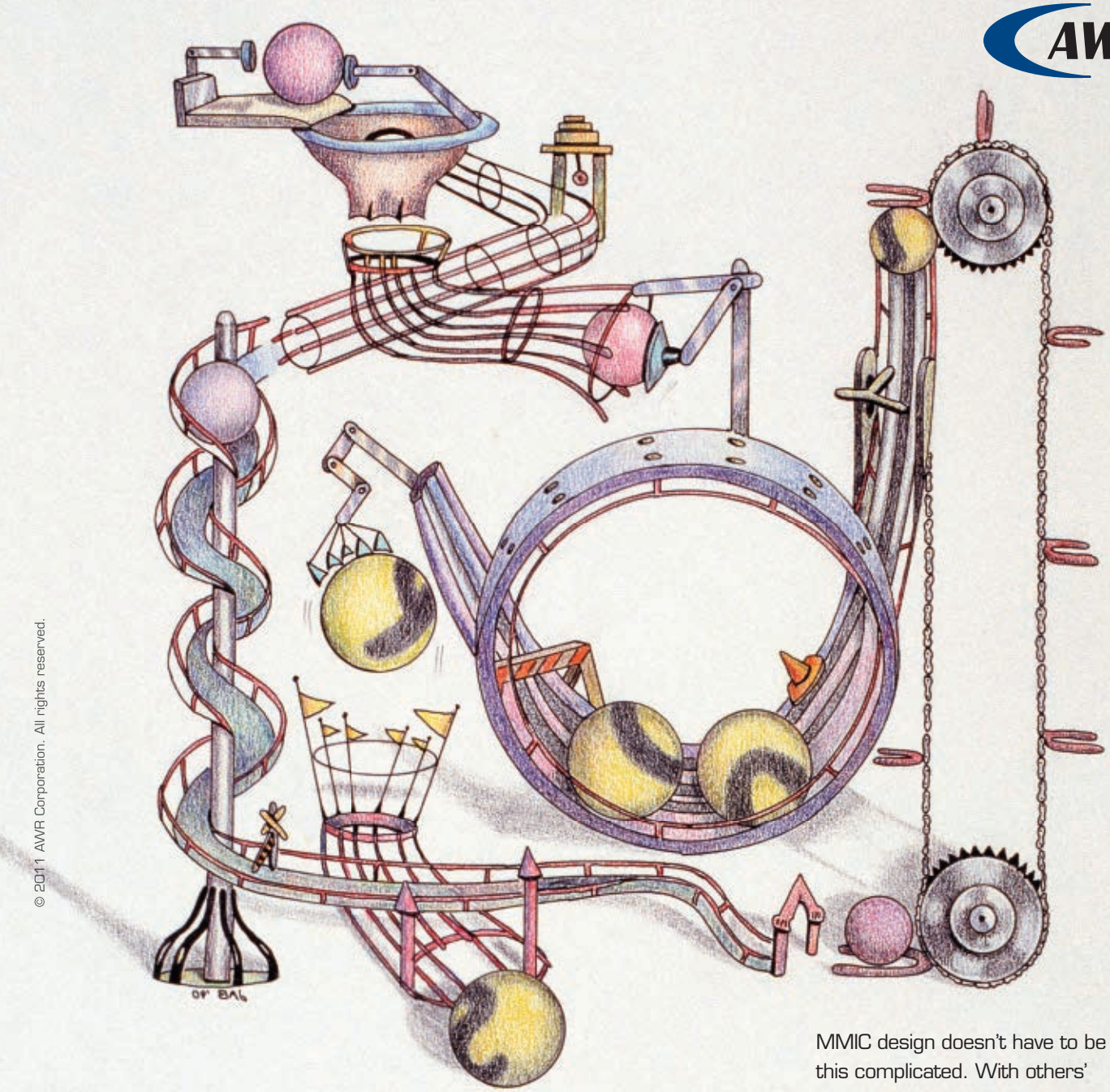

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linear device characterization (IMS MicroApps), MIMO over-the-air testing (CTIA Wireless) and Defence & Security (European Microwave Week). We believe smaller, focused expert forums are of increasing importance to RF/microwave engineers who want to stay well-informed on the latest technologies, applications and market opportunities. Look for more of them in 2012.

Of course, our industry does not operate in a vacuum and global events can have a pesky way of impacting our fate. The Tea Party-led victories of last year's mid-term election have the US government nearly grinding to a halt every other month as a divided Congress argues over spending. On the brink of letting the whole system collapse, we wait to see who blinks first – cuts to defense or entitlement spending or higher taxes for corporations and the top one percent (those scorned by Occupy Wall-Street empathizers). Meanwhile, Europe's financial house has yet to find terra firma due to the fiscal woes of its economically weak members. Ah well, it is all part of an evolving world. Change is constant, just as it was for the 19th century inhabitants of Newburyport – adapt or perish.

Consider one of the biggest events of the year – the "Arab Spring." Forget about bringing democracy to the Middle East by way of shock and awe, it was the self-immolation of a Tunisian street vendor that sparked public uprisings that brought down dictatorships in Tunisia, Egypt, and Libya and threatens those in Yemen and Syria. To be sure, the efforts of the former rebels in Libya would not have succeeded in getting rid of Muammar Gaddafi without NATO's technology and firepower providing support. Likewise, technology by way of UAV surveillance provided the necessary intelligence to make the Navy Seals successful in their operation to take out Osama Bin Laden.

Military strategists saw this dynamic at play and coined the term "asymmetric warfare." The asymmetric nature of today's battlefield can be a threat or a weapon depending on how planners engage their adversaries. The lessons of Iraq and Afghanistan showed that technology and brute strength alone do not ensure success. And so defense spending is undergoing a transformation.

According to the market research presented by Strategy Analytics in our Defence & Security Forum at EuMW, the military is interested in strengthening the capabilities of its electronics systems specifically for this new kind of engagement. Accordingly, budgets will look to upgrade systems with an emphasis on being cheaper, faster and better. Delivering on these requirements may spare your business from a devastating downturn in future defense spending cuts. If not, perhaps you should look to the emerging commercial markets in China.

The take-away is this – technology and individual effort make the difference to bring about change. Waiting for opportunities is not the same as actively seeking them. Take stock in your strengths, be knowledgeable of the changes taking place globally, align the two and let's take on the world.

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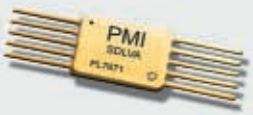

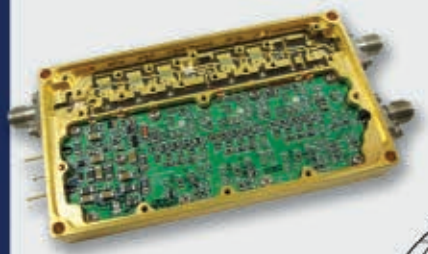

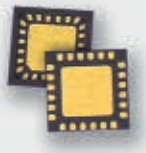

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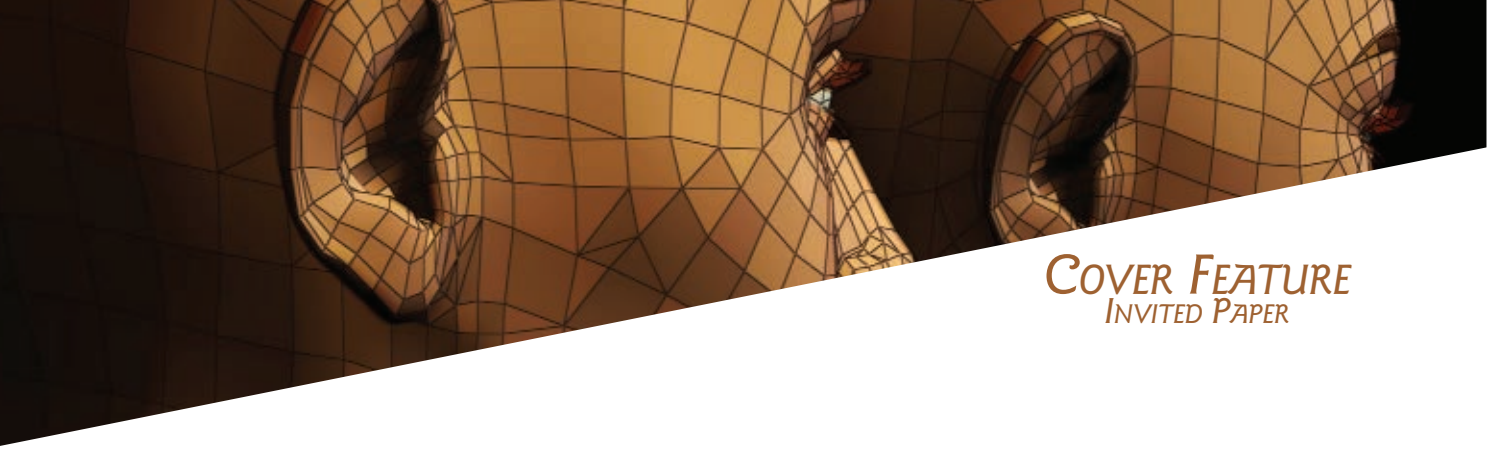

COVER FEATURE
INVITED PAPER

USING SMART PEOPLE TO FORM FUTURE MOBILE WIRELESS NETWORKS

As demand for high data rate applications on the move continues to rise, cellular network and mobile hardware designers will continue to vigorously push the boundaries on the maximum rate at which information can be transmitted over wireless communications channels. One exciting possibility to supplement mobile communications is to use network users themselves as relays by employing cooperative communications. In this article we introduce the concept of a body-to-body network, where smart communicating devices carried or worn by a person are used to form a wireless network with devices situated on other nearby persons. By using body-to-body networks operating in the popular Industrial, Scientific and Medical bands, it will be possible to complement and extend existing infrastructure networks by supporting network capacity, improving data rates and promoting green spectrum usage. We present the results of some illustrative experiments that will help to quantify the impact of the human body and related movements on signal reception and their implications in body-centric system design.

Recent years have seen significant uptake of new so-called "smart phones" where the end user has access to a host of different functionality such as e-mail, web browser, media player, positioning information and on-board high definition (HD) video camera as well as the ability to make voice calls. New innovations in this area will see the form factor of smart devices being modified, so that they may be worn on the human body (for example, Sony's Nextep concept) or integrated into clothing, in the process creating a new generation of "smart" people. This explosion of intelligent technology and its associated high bandwidth requirements will place increased demands on mobile wireless networks. This high demand for data services is already being experienced in densely populated areas, such as sports venues, rail stations and airports. Network and service providers are currently trying to meet these needs through the introduction of long term evolution (LTE) and WiMAX technologies which aim to provide individual networks users with multi-megabit data rates. Another popular measure, which aims to alleviate the strain on cellular networks and extend the range of data services into difficult to reach and densely populated areas, is the use of WiFi hotspots.

While network operators are already planning for the fourth generation (4G) of cellular wireless standards to include the implementation of LTE Advanced capable networks, another as-of-yet unexplored possibility, which may help to sustain high data rates and extend the range of infrastructure networks, is to use the network users themselves as simplified ad hoc base stations. This will be achieved by creating vast body-to-body networks of interlinked wireless devices, carried, worn or integrated

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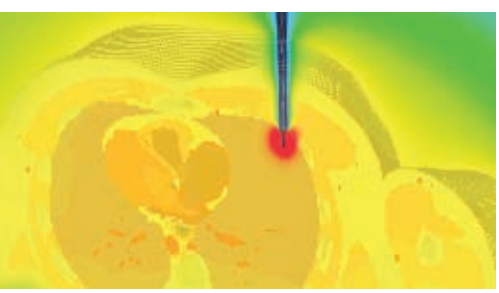

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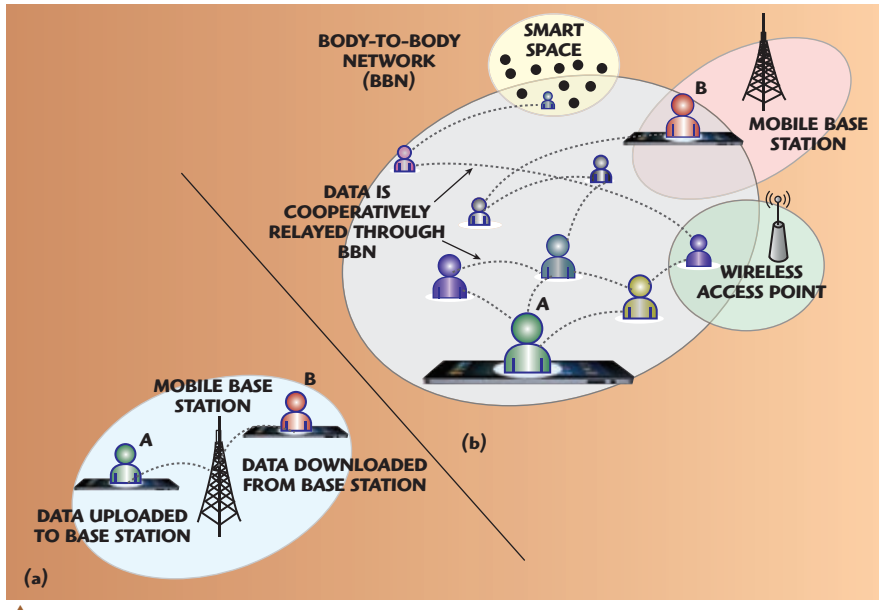
CHANGING THE STANDARDS

into clothing. These networks will allow data to be routed from person-to-person before being forwarded to the recipient or the relevant infrastructure network if necessary. In the creation of body-to-body networks there will be many issues that will impact the design of physical and medium access layers. In this article, we briefly discuss some of these issues before focussing on how the human body itself will affect these links.

BODY-TO-BODY NETWORK CONCEPT

In its simplest form, a body-to-body network (BBN) is a type of mobile ad hoc network in which constituent wireless nodes are either carried or worn by people. By creating vast cooperative BBNs in densely populated areas, cellular network providers have opportunity to truly achieve "anytime, anywhere" connectivity and multi-megabit or even gigabit download rates (if using ultra short-range millimeter-wave communications[1]). The term "cooperative" relates to the idea that all users of a BBN should contribute a nominal amount of their bandwidth to forward data relayed by other network users, thus acting in a cooperative manner for the greater benefit of the network. To illustrate the concept of a BBN and how it could be used to support mobile communications, consider the simple, but relatively common scenario depicted in ***Figure 1a***. Here we have two cellular network users who wish to transfer data (for example, video, music or just social networking information) to one another within the same network cell. Using traditional cellular architecture, the data originating from person A would be routed through the local base station to person B. Now consider the identical communications process, whereby person A wishes to send data to person B who is still within the locality except this time, they will use a BBN to cooperatively relay the data. This scenario is shown in ***Figure 1b***, where instead of uploading the data to the nearby base station, person A transmits the data over a much shorter distance to other BBN users in a local vicinity. The data is then routed through the BBN until it reaches the intended recipient, person B. Among the key benefits of body-to-body networking are that it provides the opportunity for both multicasting and multiplexing of the data. In the case of multicasting, multiple copies of the data are sent purposely to multiple recipients. In multiplexing, used, for example, in large file transfer (such as, HD video), the data may be broken into smaller components by the sender's smart device before taking separate network paths through the BBN and being reassembled by the recipient.



▲ *Fig. 1 Data communications between two cellular network users, persons A and B, who are (a) within the same network cell and (b) using a BBN.*

Antenna techniques like sectorization and channel access technologies, such as wideband code division multiple access (W-CDMA) and the orthogonal frequency-division multiple access (OFDMA) scheme used in LTE, promote frequency reuse within cellular networks. In BBNs, because signal propagation is likely to occur over distances of a few meters to a maximum of 100 meters, frequency reuse can be achieved over much shorter distances, in the process promoting so-called "green" spectrum usage. Furthermore, because BBN users are transmitting over much shorter distances, the power amplifier in the smart device's transmit chain used for body-to-body communications will not be required to operate with as high an output level, in the process saving valuable battery energy. As shown in Figure 1b, BBNs will complement existing infrastructure based networks by extending their coverage into difficult to reach places such as indoor environments, as it only takes one person within a BBN to be connected to a particular infrastructure network and this person (node) can act as a gateway for the whole BBN. In the long term, this may have the added benefit of helping to reduce controversial base station densities in areas like city centers.

ISSUES AFFECTING BBNS

Applications of body-to-body networking will extend well beyond the support of cellular and Wi-Fi networks as described above. They will also be used in short-range covert military applications,[1] first responder applications,[2] team sports and used to interconnect body area networks (BAN).[3] In this respect, the wireless technology used to interconnect body-worn devices will ultimately depend on the application. For example, low data rate applications, such as positioning and health monitoring systems likely to be used by first responders, may utilize technologies like ZigBee[4], which operates in unlicensed worldwide frequency allocations in the 868/915 MHz and 2.45 GHz Industrial, Scientific and Medical (ISM) bands. To complement cellular and other infrastructure networks, BBNs may operate using mobile ad hoc networking based on WiFi. The main reasoning and advantage here is that many smart devices already feature WiFi chipsets that could be used for communications.

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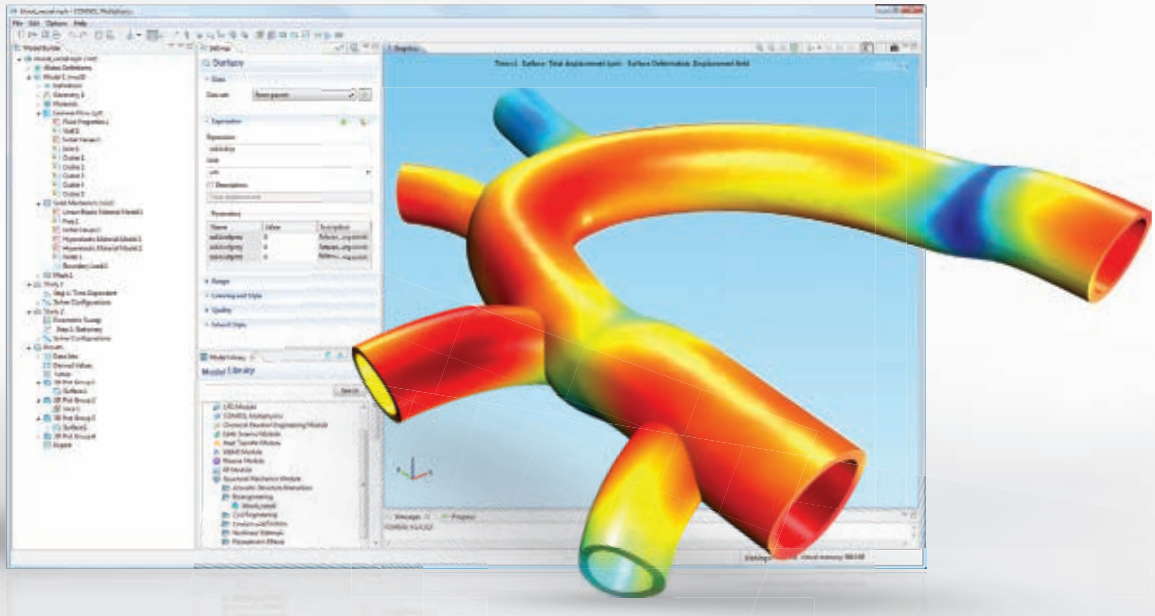

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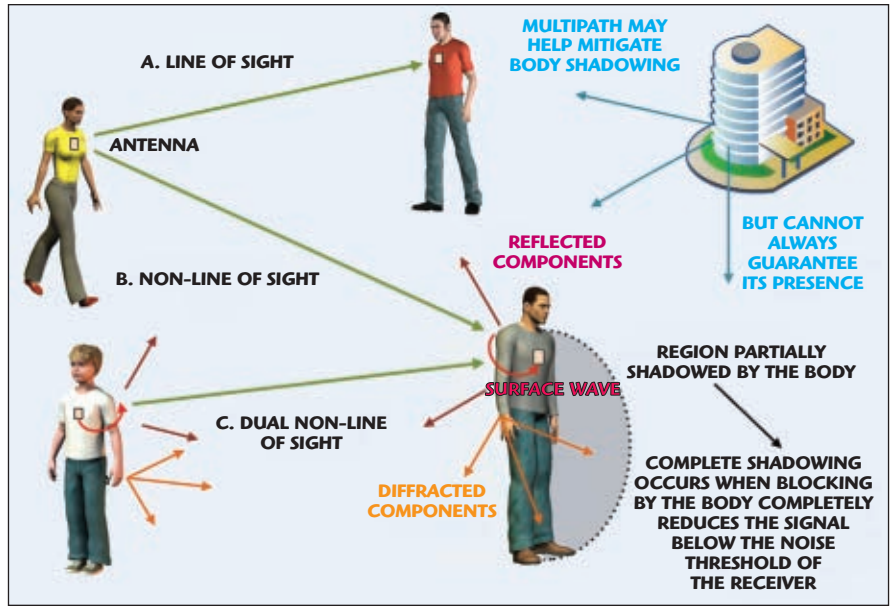
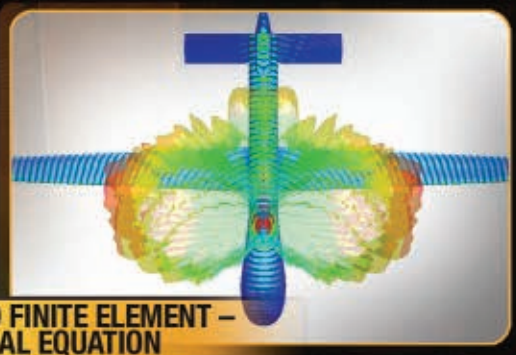


▲ *Fig. 2 Illustration of the most common communication scenarios: (a) LOS, (b) NLOS where one body obstructs the LOS path and (c) dual-NLOS where both bodies obstruct the LOS path.*

work, the use of BBNs to supplement cellular and other infrastructure networks will mean that communications are susceptible to increased latency due to the additional hops required to route traffic. Security will also be a major issue as routing between multiple nodes will increase the risk of unauthorized access and compromise sensitive data. This will add complexity to the medium access layer (MAC) and network management. At candidate ultra-high frequency (UHF) and microwave frequencies, hardware designed to operate in BBNs, such as antennas, will be subject to time varying electromagnetic interaction effects. These include near-field coupling, radiation pattern distortion and shifts in antenna impedance,[5,6] which may degrade the efficiency of the body-worn system and reduce signal reliability. Successful operation of physical layer (PHY) attributes, such as antennas, transceiver hardware and modulation schemes, will also be dependent upon a thorough knowledge of the radio propagation channel, which is discussed next.

SIGNAL PROPAGATION IN BBNS

Body-to-body communication channels[2] found in BBNs differ significantly from conventional fixed-to-mobile or off-body channels,[7] where the base station is fixed, typically elevated and often relatively free of local scattering. ***Figure 2*** shows three of the main communication scenarios likely to be encountered in body-to-body networking. In these examples we have assumed that the antennas are positioned on each person's front central chest region although, in reality, communications equipment used for BBNs could be carried or worn on any region of the body. To illustrate the impact of some of these scenarios on narrowband signal reception in BBNs, we use the results of some representative experiments conducted at the ISM frequency of 2.45 GHz.[8] In these experiments, a novel flexible patch antenna (see ***Figure 3***) that was designed to be resonant on the human body with a peak gain in the off-body direction of +6.2 dBi and –10 dB bandwidth of 55 MHz (2.398 to 2.453 GHz) was placed at the front central chest region of two male test subjects using a small strip of Velcro® and without the use of a dielectric spacer. The measurement hardware used in these trials consisted of the body sensor node (BSN) platform developed by Imperial College London. The transceiver section of the node utilized a Texas Instruments CC2420,[9] which has a linear dynamic operating range of approximately 100 dB, maximum transmit power of 0 dBm and a receive sensitivity of –95 dBm. A transmitter node attached to person A was configured to transmit a continuous wave signal with a power level of 0 dBm at 2.45 GHz. The receiver



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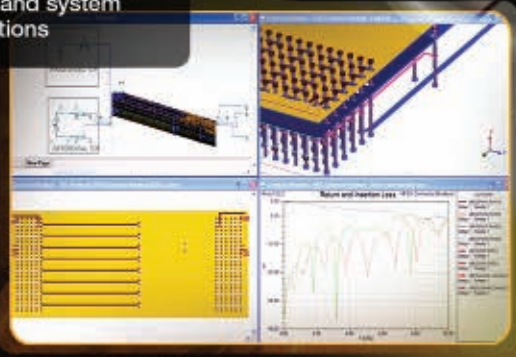

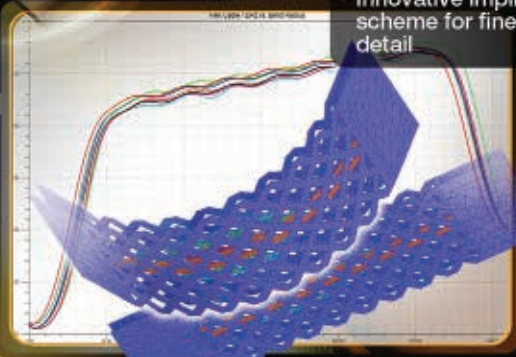

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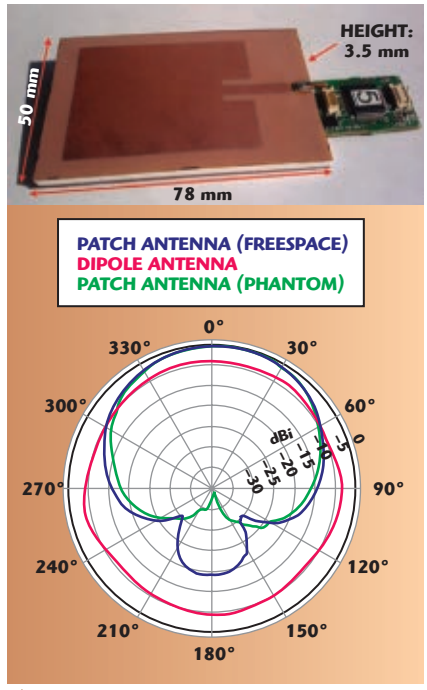

Fig. 3 Wearable flexible antenna attached to BSN node along with radiation patterns.

node was then attached to person B and was programmed to record the 8-bit received signal strength indicator (RSSI) obtained from the CC2420 every 16 ms. To limit the influence of environmental multipath and, hence, ensure the variations in the received signal level were due to the human body itself, the measurements were conducted in a low multipath outdoor environment.[8]

SCENARIO A (LOS)

If we initially ignore environmental multipath, scenario A illustrates the situation where two persons face each other with an antenna positioned on the front of the body. In this case, signal propagation will be predominantly via line of sight (LOS) through free space propagation, with some supplementary multipath contributions caused by scattering and reflection from the body surface. Because of this, it is necessary to add two extra parameters to the popular log-distance path loss model commonly used by wireless engineers to estimate signal loss over distance. These two parameters account for body shadowing (X_{BS}), slower physiological processes and small movements (X_{SM}), such as, rapid fluctuations in the signal due to much smaller changes in body posture akin to small scale fading. Examples of slower physiological processes are respiration and biomechanical actions, such as movement of the limbs. In Equation 1, P_0 (dB) is the path loss measured at a reference distance (in these experiments, 1 m), n is the path loss exponent, d is the distance between the transmit and receive antennas and d_0 is the reference distance.

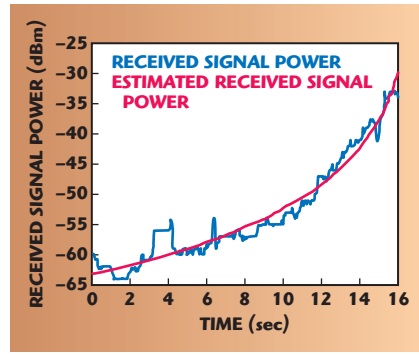

Fig. 4 Received signal power and estimated signal power as person A walked in LOS toward person B from 15 to 1 m points.

$$P_{(dB)} = P_{0(dB)} + 10n \log(d/d_0) + X_{BS(dB)} - V_{SM(dB)} \quad (1)$$

Figure 4 shows the measured received signal power as person A walked in a straight line toward person B from a position 15 m away. To calculate the estimated received signal power at a particular distance in person A's journey toward person B, time was translated to distance using the estimate of person A's walking speed (~0.88 m/s). Using Equation 1 and converting the measured received signal power to path loss, the exponent n and path loss at the reference distance were calculated and found to be n = 2.9 and P_0 = 29.6 dB.

Similar to shadow fading in mobile communications channels, the X_{BS} component of the received signal is assumed to follow a lognormal distribution. Lognormal random variables can be viewed as the result of a number of multiplicative factors that become additive under logarithmic transformation. The μ and σ parameters of the lognormal PDF most likely to have generated the X_{BS} component of the signal were found to be μ = 0 and σ = 0.2. In mobile communications channels, it is often assumed that the short-term fading component of the received signal is subject to Rayleigh fading. In Rayleigh fading, the received signal is viewed as the resultant of a large number of scattered signal

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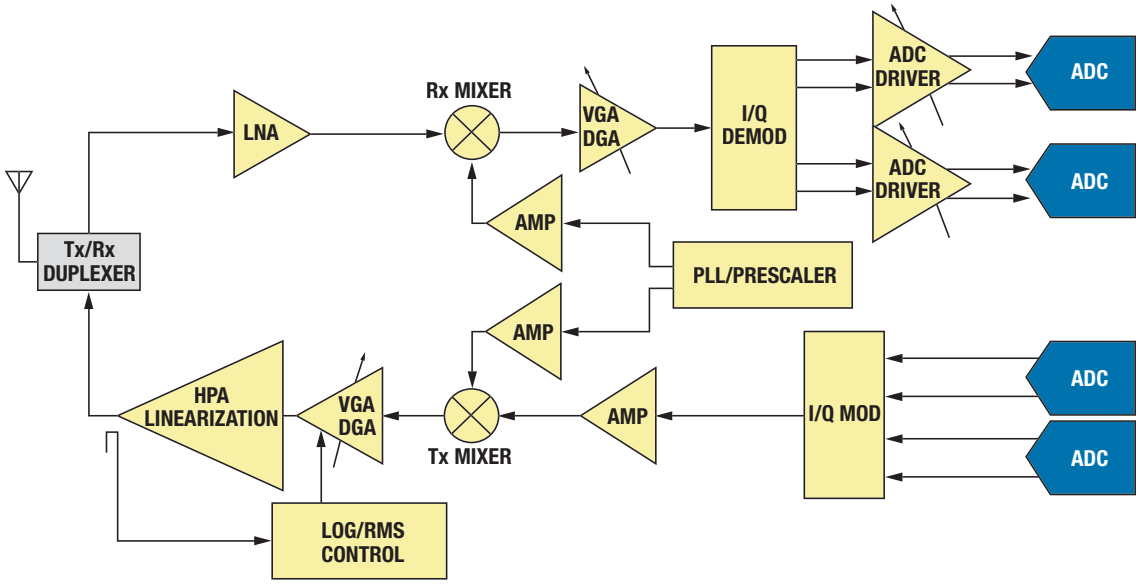

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components arriving at the receiver, each with random amplitude and uniform phase. In body-to-body communication channels, where a dominant signal component (LOS or strong on-body reflection) may exist, it will be more appropriate to model the received signal as exhibiting Ricean fading,[10] which assumes a scattered signal component alongside a single signal component, which dominates over the scattered signal. An important figure, associated with Ricean fading is the Ricean-K factor. The Ricean-K factor is used to characterize the degree of fading in a wireless channel and is defined as the ratio of the square of the dominant component (A^2) to the average scattered power ($2s^2$), such as, $K = A^2/2s^2$. When $K \rightarrow 0$ and hence the dominant component A decreases, the fading becomes closer to Rayleigh fading, and as $K \rightarrow \infty$, the channel no longer exhibits fading. The Ricean-K factor for this scenario was extremely large ($K \sim 200$), which shows that under direct LOS conditions and in body-to-body communications channels, there is very little fading due to small body movements.

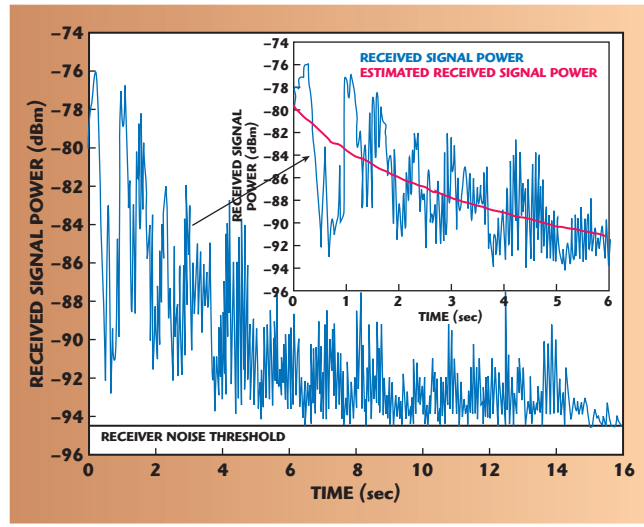

Fig. 5 Received signal power and estimated signal power as person A walked in NLOS away from person B from 1 to 15 m points.

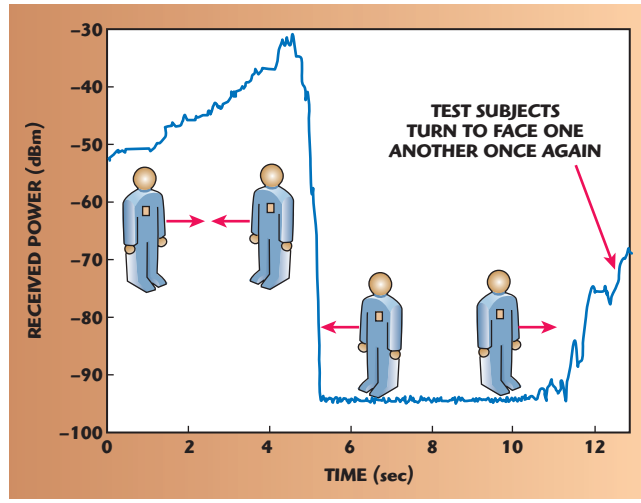

Fig. 6 Received signal power as persons A and B walk toward each other from a separation distance of 5 m, meet at the 2.5 m point and turn to walk back to their starting positions.

SCENARIO B (NLOS)

At UHF and microwave frequencies, the human body acts as an inhomogeneous interfering object. Thus, as shown in scenario B, when one of the persons turns so that his body obstructs the main LOS signal path, the communications link becomes dependent on diffracted, reflected, scattered and trapped surface wave components. As shown in Figure 2, this complex propagation scenario creates a signal shadowing region at the front of the person, a mechanism commonly referred to as human body shadowing.[11] Additionally, when the desired signal falls below the noise threshold of the receiver, complete shadowing will occur.

Figure 5 shows the received signal power as person A walked in NLOS from a distance of 1 m from person B to a point 15 m away. One issue that became evident from this scenario, which will have implications for the future design of hardware to be used in BBNs, is the dynamic range required for operation. Even though the receiver section of the CC2420 has a linear dynamic operating range of approximately 100 dB, for scenarios where one body shadows the direct LOS path and when the

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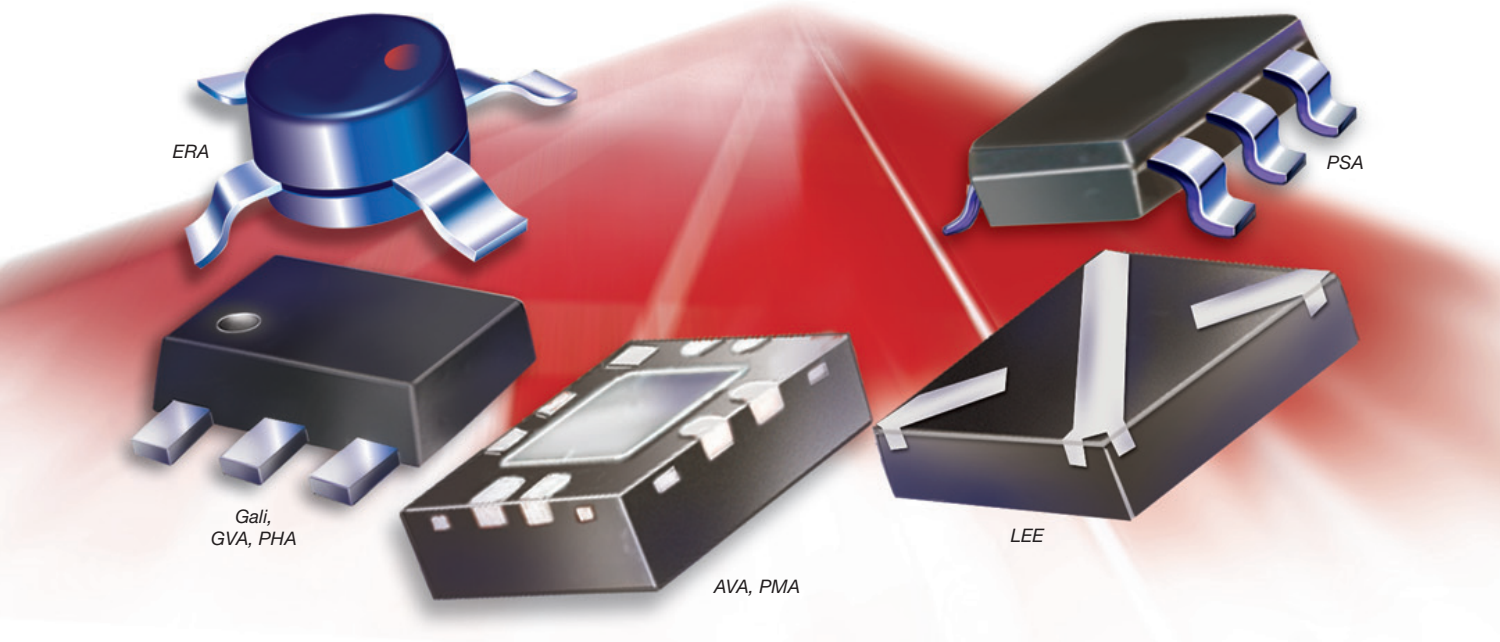

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straight line distance between the two persons exceeded 6 m, the received signal power regularly entered the region beyond the noise threshold of the receiver. Because of this, only the first 6 s of this scenario were used for this analysis (inset shown in Figure 5). While it could be argued that a more omni-directional antenna may help to sustain the link in this scenario, the subsequent reduction in antenna gain may reduce the distance over which the hardware could effectively operate.

Equivalently, if an extra gain stage is introduced to the transmit and receive chains, it will significantly reduce battery life or increase the size of the device if a greater capacity battery is used. Using the same procedure for treating the data as in scenario A, the parameter estimates for the path loss in this scenario were $n = 1.5$ and $P_0 = 79.6$ dB. It can be seen quite clearly that for body-to-body signal propagation in which one person's body completely shadows the direct LOS an extra 50 dB signal attenuation occurs compared to the LOS case. This undesirable consequence of body shadowing is further exacerbated by an increase in the spread of the X_{BS} component of the received signal ($\mu = 0.02$ and $\sigma = 0.28$). Additionally, the Ricean-K factor of the X_{SM} component was significantly reduced ($K \sim 18$) although this value infers that a dominant signal component still exists.

SCENARIO C (DUAL-NLOS)

The situation depicted in scenario C, where both persons' bodies now obscure the main LOS, may be viewed as one of the most complicated signal propagation scenarios to analyze and indeed compensate for in BBNs. To examine this scenario, persons A and B stood with an initial at a separation distance of 5 m in an outdoor environment. They then proceeded to walk toward each other, meeting at the 2.5 m point before turning and walking back to their starting positions. What is immediately obvious from ***Figure 6*** is that, even at very short separation distances, the communications link in a BBN will be heavily susceptible to dual-body shadowing events. This can be seen from the time series at approximately 4 to 6 seconds as the two persons begin to turn, the received power level immediately begins to deteriorate, eventually dropping below the noise threshold of the BSN node when the persons finally enter dual NLOS channel conditions. Therefore, not only will wireless hardware designed to operate in BBNs have to contend with significant variations in received signal levels, but protocols will have to be resilient to extended periods of outage and have the ability to readily reroute communications through other nearby BBN users.

MITIGATION OF BODY SHADOWING AND FADING

Antennas: Antennas designed to operate in body centric communications systems may be broadly categorized as on- or off-body radiators, according to their radiation pattern characteristics when mounted on the human body. As shown in Figure 3, the patch antenna used for the examples described above was designed to provide maximum gain in an off-body direction. This will be advantageous in BBNs when it is desired to have communications that occur over ex-

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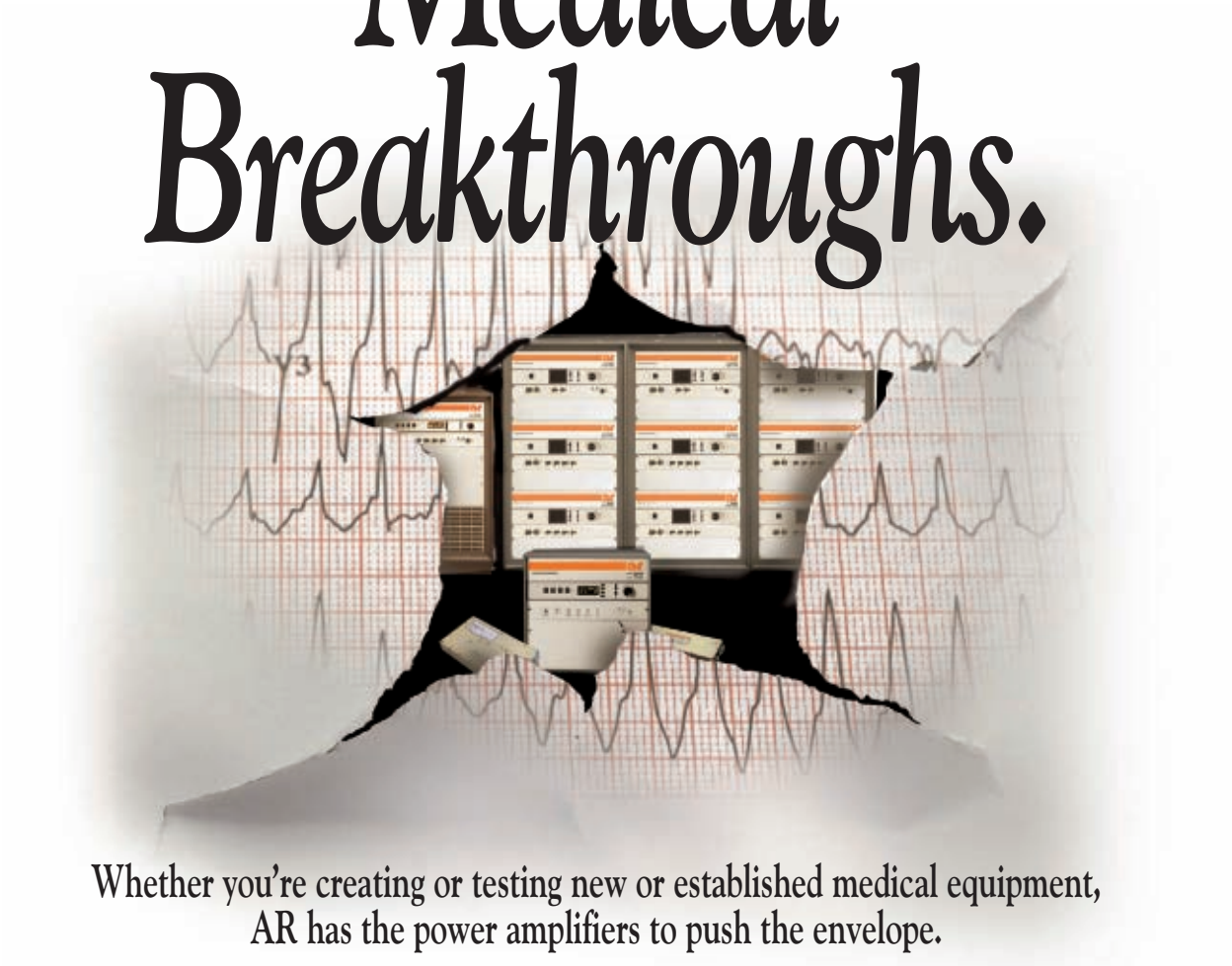

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tended distances. However, as shown for scenarios B and C, because of the relatively directive radiation characteristics, this type of antenna can suffer from the effects of body shadowing. On-body antennas, because of their application space, are typically designed to maximize electromagnetic radiation across the body surface and minimize radiation in an off-body direction. While this may seem counterintuitive for body-to-body applications, an on-body mode of propagation may prove advantageous in dual NLOS situations as electromagnetic waves will be forced out and around the side (toward the back) of the human body using trapped surface and diffracted wave modes of propagation. Thus, new hybrid on/off body antennas, such as the one proposed in Scanlon and Chandran,[12] which have the ability to electronically switch between on- and off-body modes may prove indispensible for future BBN communications, especially in dual NLOS channels where there is insufficient environmental multipath available to sustain the link.

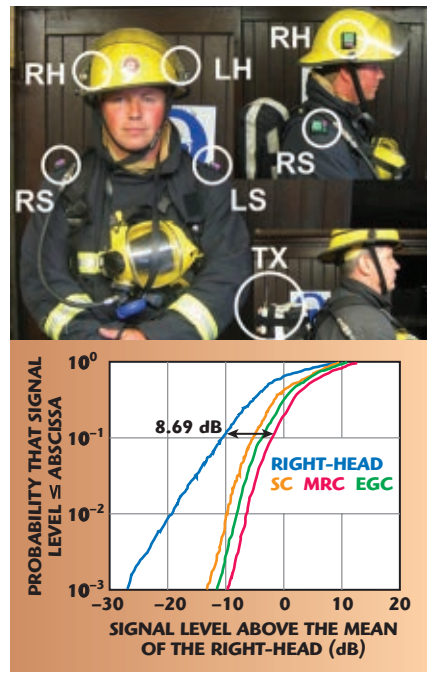

Fig. 7 Antenna arrangement for four branch diversity systems with empirical cumulative distribution functions (CDF) for various configurations.

Spatial Diversity: Another possible method of improving PHY layer performance may be to use diversity combining based on multiple, spatially separated antennas. Distributing antennas in smart garments will facilitate greater spacing, reducing negative effects associated with diversity arrangements in mobile handsets such as undesired correlation and mutual coupling. For example, consider the highly demanding application of first responders attending an emergency within a building.[2] Using the distributed antenna system shown in ***Figure 7***, operating at the ISM frequency of 2.45 GHz with a maximal ratio combining scheme, up to 8.69 dB diversity gain can be made available at 90 percent signal reliability when four spatially separated antennas are used at the receiver. Empirical cumulative distribution functions (CDF) are shown for the right-head positioned antenna, four branch selection combining (SC), maximal ratio combining (MRC) and equal gain combining (EGC). Note that all CDFs are relative to the mean of the branch with the highest mean signal level (right-head). By using multiple antennas at both ends of a body-to-body communica-

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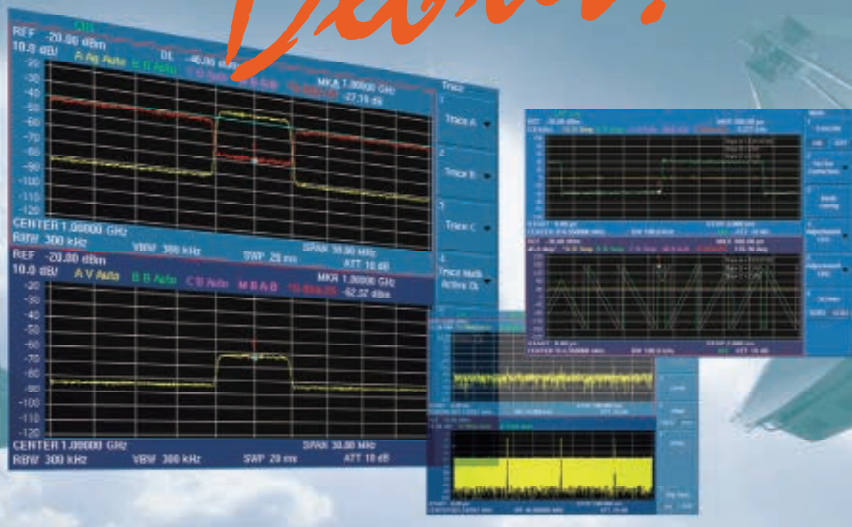

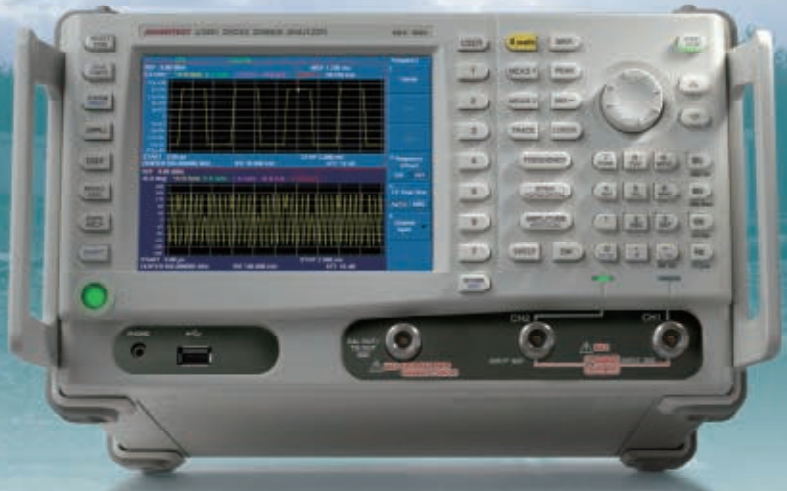

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tions link, it will then become possible to use multiple-input multiple-output (MIMO) communications to exploit body shadowing to provide independent signal paths, which can be used to increase throughput.

FUTURE OF BBNS

In this article we have introduced the concept of a BBN, and how these new networks could be used to complement current cellular and other infrastructure networks by supporting data transmissions and extending their operating ranges. While there will be many design challenges at the PHY and MAC layers, using the ISM frequency of 2.45 GHz likely to be used by the first generation of BBN applications, we have shown some of the effects of human body movement and orientation on received signal characteristics. Most notably, the communications link between two wearable devices in a BBN will be particularly affected when either one or both persons' bodies obstruct the main LOS path.

Mitigation of body shadowing will most likely come in the form of innovative antenna design and multiple antenna systems, such as diversity and MIMO, made possible by the fabrication of fashionable smart garments. Recent advancements in millimeter-wave technology mean that it will soon be feasible to use ISM frequencies in the 59 to 66 GHz range to provide high bandwidth capabilities for a range of BBN applications. The propagation characteristics at this part of the spectrum will provide many benefits for short-range body-to-body communications, especially in densely populated areas. For example, the higher path loss, when compared to the microwave region of the radio spectrum, will mean BBN users will benefit from even better frequency reuse due to much shorter hops as well as the potential of achieving data rates in excess of 2 Gb/s. Furthermore, the short signal wavelength ($\lambda \approx 5$ mm), will also support the development of truly miniaturized devices that will be ideal for wearing on the human body or integration into clothing. ■

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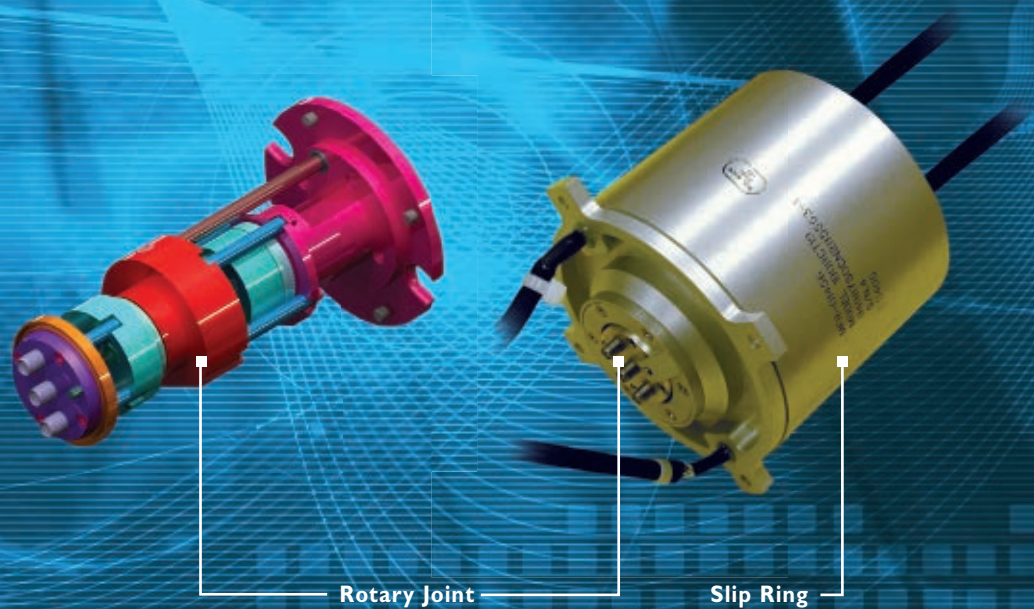

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includes the reflector and ortho-mode transducer.

CST DESIGN STUDIO

The user accesses SAM through the familiar CST DESIGN STUDIO (CST DS) interface, which is part of every CST STUDIO SUITE installation, because it employs the CST DS task concept. This task concept has been enhanced significantly in version 2012. Most importantly, it enables the set-up of nested task structures to run, for example, optimization within parameter sweeps.

Accessing, sorting and filtering of the results data is greatly simplified by a new table view. CST DS 2012 also features a built-in component library that enables access to components from various vendors, such as ON Semiconductor and STMicroelectronics.

CST MWS TRANSIENT SOLVER

The well-established CST MWS transient solver has undergone many improvements, in particular with respect to material handling, for example for surface impedance, broadband constant tan(δ), and higher order dispersive magnetic materials, as well as transparent sheets. It also features a field-dependent material model, which allows the modeling of electric breakdown phenomena, such as ignition of RF plasma. The broadband sensitivity analysis with respect to geometry and material property variation has also been enhanced.

BI-DIRECTIONAL COUPLING

Coupling between fields and complex cable bundles is bi-directional; cables can both receive and re-radiate electromagnetic fields. Depending on the routing/position of cables within an enclosure, the field distribution, modes and current paths can be strongly affected, and only considering one-way coupling may produce inaccurate results.

CST STUDIO SUITE 2012 enables true transient bi-directional field/cable coupling to be simulated for complex cable bundles routed through complex 3D environments, such as electronics enclosures, aircraft and automobiles. Accurate analysis can be performed efficiently, despite the huge difference in scale between cable cross-section dimensions and overall system/vehicle dimensions. ***Figure 2*** shows a model of a cable harness inside an Apache helicopter for EMP analysis.

FEM FAST RESONANT SOLVER

With version 2012, a new fast resonant solver based on FEM has been introduced. It features curved elements of arbitrary order that enable a conformal representation of the geometry, which improves the simulation accuracy. The solver performs a model order reduction (MOR) and derives S-parameters and fields from this model. It outperforms the general purpose solver for applications that require a large number of samples for an accurate frequency sweep, such as higher order filters or structures designed for a very wide frequency band.

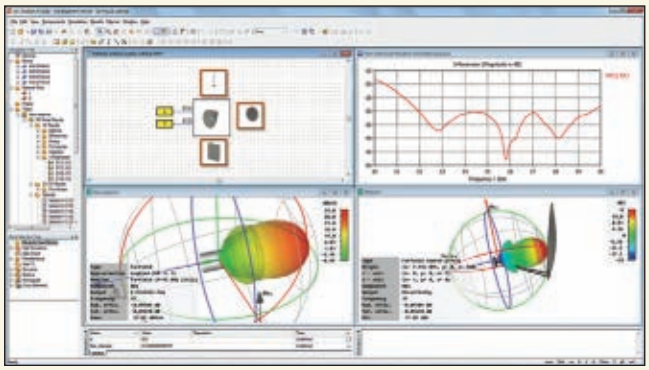

Fig. 1 System Assembly and Modeling: various simulation projects can be derived from one master project.

Fig. 2 Model of a cable harness inside an Apache helicopter for EMP analysis: inset pictures show the cable cross-section at different locations.

EIGENMODE SOLVER

Alongside the Finite Integration Technique based Eigenmode solver, CST MWS now features an alternative Eigenmode solver, which uses the Finite Element Method. It also employs curved elements. In combination with the unstructured FEM grid, which can resolve small structure details very efficiently, it can increase the simulation performance dramatically.

MULTI-LAYER SOLVER

CST MICROWAVE STUDIO (CST MWS) version 2012 comes with a new MoM solver, which solves planar, multi-layer geometries both accurately and efficiently. The layer stack can be generated automatically from 3D models. The geometry does not need to be strictly planar: 3D elements can also be included. Additionally, the solver features open boundaries and automatic edge mesh refinement, as well as automatic de-embedding of ports. Typical application areas are RF designs, such as planar antennas and filters, as well as MMIC and planar feed network designs. It can also plug-in to SAM.

AUTOMATIC OPTIMIZATION

CST STUDIO SUITE features versatile algorithms for local and global optimization, such as the Nelder-Mead Simplex Method, Particle Swarm optimizers and the Trust Region Method, for which convergence can be further accelerated by employing sensitivity information. New to version 2012 is the CMA-Evolution Strategy, a powerful global optimizer with good convergence behavior.

HPC

High performance computing (HPC) continues to be a hot topic. The CST simulation acceleration scheme employs graphical processor units (GPU), clusters, or simply an array of computers in a network, to speed up simulations. New in version 2012 is support for Nvidia's latest GPU generation, not only by CST MWS but also by CST PARTICLE STUDIO, CST's software dedicated to the simulation of electron devices, such as traveling wave tubes and magnetrons.

The System Assembly and Modeling approach of CST STUDIO SUITE 2012 is entirely focused on simplifying electromagnetic system simulation by applying innovative simulation and optimization technology to either full EM systems or components thereof. This latest version includes a wide range of improvements that both increase speed and versatility and significantly enhance the user experience.

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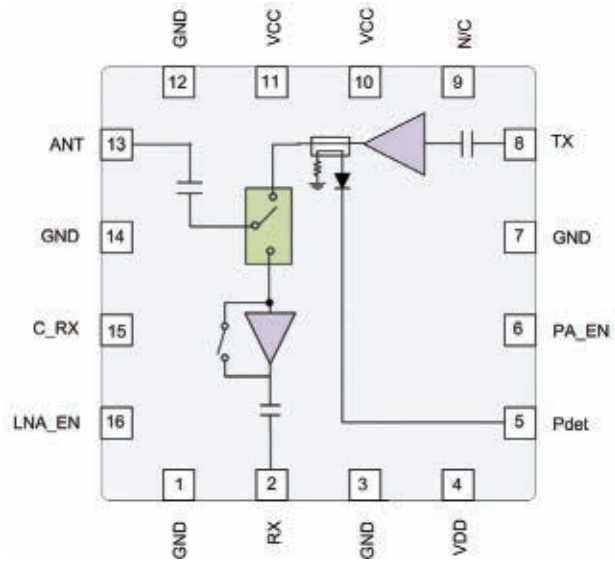
SPECIFICATIONS

Freq Range (Min) (MHz)	*Freq Range (Max) (MHz)*	*P_{OUT} (dBm)*	*EVM (%)*	*Gain (dB)*	*V_{CC} (V)*	*I_{CC} (mA)*	*Package*	*Part Number*
2.4	2.5	18	2	24	3.3	230	Laminate	RFFM8200
5.15	5.85	16	2	30	3.3	250	Laminate	RFFM8500



FEATURES

- Integrated 2.5GHz b/g/n amplifier, LNA with bypass mode, SP3T switch, and power detector coupler (RFFM8200)
- Integrated 5GHz amplifier, SPT2T TX/RX switch, LNA with bypass, and power detector coupler (RFFM8500)
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UNDERNEATH THE HOOD OF 802.11AC

In a recent market study, researchers estimated that by the year 2015, manufacturers will be shipping more than a billion IEEE 802.11ac radios annually. The figure is impressive, especially because 802.11ac does not yet exist as a public standard. So one may be wondering, "What is this 802.11ac specification and how is it different from today's Wi-Fi?"

A few years ago, some of the world's first 802.11n Wi-Fi products hit the market labeled as "draft-n" compliant. Of course, these routers and access points used the "draft-n" moniker for specific reasons – the standard did not exist yet. Today, 802.11n products are everywhere and it has become widely accepted as the preeminent Wi-Fi standard. However, just like many 802.11g products have largely moved on to 802.11n, the next generation of Wi-Fi will be based on the 802.11ac specification.

TABLE I

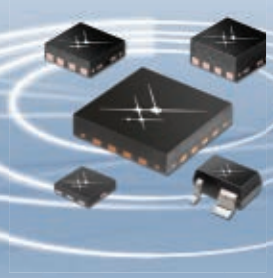
NEW GENERATIONS OF WI-FI INVOLVE EVOLUTIONARY CHANGES IN THE PHYSICAL LAYER SPECIFICATIONS

	802.11a/g	*802.11n*	*802.11ac*
Antenna Configuration	1×1 SISO	4×4 MIMO	8×8 MIMO
Highest Order Modulation	BPSK to 64 QAM	BPSK to 64 QAM	BPSK to 256 QAM
Channel Bandwidth	20 MHz	20 and 40 MHz	20, 40, 80, 80 + 80, and 160 MHz
Year Introduced	1999 (802.11a) 2003 (802.11g)	2009	2012 (estimated)

The motivation for the new 802.11ac specification is primarily based on the requirement for higher data throughput. In the past few years, Wi-Fi has moved from 802.11a/b to "g" to "n." The 802.11ac very high throughput (VHT) specification promises substantially higher data rates. This article will walk through some of the fundamental enabling features of the physical layer that allow the specification to support higher throughput. More specifically, evolutionary characteristics, such as the implementation of use of wider channel bandwidths, changes in modulation type, the use of more spatial streams and the possible data rates, will be described.

Table 1 compares some basic physical layer specifications of both the past and future generations of Wi-Fi. The primary new feature introduced in 802.11n specification was the use of more spatial streams through the introduction of 4×4 MIMO technology. In the 802.11ac, the maximum spatial streams have moved to eight with 8×8 MIMO. In addition, other notable changes are the optional use of 160 MHz channel bandwidth and the introduction of the 256 QAM modulation scheme.

DAVID A. HALL
National Instruments, Austin, TX



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SKY67101-396LF	Cellular Infrastructure	400–1200	900	17.5	0.57	34	19	4 (3.3–5.0)	54 (20–90)	DFN 8L 2 x 2 x 0.75
SKY67100-396LF	Cellular Infrastructure	1200–2300	1950	17.5	0.7	34	18.5	4 (3.3–5.0)	55 (20–90)	DFN 8L 2 x 2 x 0.75
SKY67102-396LF	Cellular Infrastructure	2000–3000	2600	17.2	0.8	34	15	4 (3.3–5.0)	50 (20–90)	DFN 8L 2 x 2 x 0.75
SKY67001-396LF	Cellular Infrastructure	700–1000	900	17.5	0.6	40.5	21	5 (3.3–5.0)	100 (50–120)	DFN 8L 2 x 2 x 0.75
SKY67002-396LF	Cellular Infrastructure	1600–2100	1950	17.5	0.65	39.5	20	5 (3.3–5.0)	95 (50–120)	DFN 8L 2 x 2 x 0.75
SKY67105-306LF	Cellular Infrastructure	600–1100	850	37	0.7	41	26	5 (3.5–5.0)	140 (120–155)	QFN 16L 4 x 4 x 0.90
SKY67106-306LF	Cellular Infrastructure	1500–3000	1950	35	0.65	37	24	5 (3.5–5.0)	100 (80–125)	QFN 16L 4 x 4 x 0.90
SKY67014-396LF	General Purpose	1500–3000	2450	13	0.95	26	15	3.3 (1.8–5.0)	15 (5–30)	DFN 8L 2 x 2 x 0.75
SKY65047-360LF	GPS and ISM Band	400–3000	1575	16.6	0.8	19.5	0	3.3 (2.7–3.8)	7 (6.5–7.5)	DFN 8L 2 x 2 x 0.90
SKY65050-372LF	Broadband Low Noise FET	450–6000	2400	15.5	0.65	23.5	10.5	3 (2.7–3.8)	20 (5–55)	SC-70 4L 2.2 x 1.35 x 1.1
SKY65404-31	5.8 GHz WLAN and ISM Band	4900–5900	5800	13	1.2	20	9	3.3 (2.8–5.0)	11 (10–15)	DFN 6L 1.5 x 1.5 x 0.45
SKY65405-21	2.4 GHz WLAN and ISM Band	2400–2500	2450	15	1.1	24	15	3.3 (2.8–5.0)	12 (10–16)	DFN 6L 1.5 x 1.5 x 0.45

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USE OF WIDER CHANNEL BANDWIDTHS

Up until the age of MIMO, the Shannon-Hartley theorem was generally regarded as the primary model of theoretical data throughput through a given digital communications channel.

$$\text{Capacity} = \text{Bandwidth} \times \log_2\left(1+\text{SNR}\right) \quad (1)$$

According to the theorem, data rates through a particular channel can only be increased by affecting either channel bandwidth or signal-to-noise ratio (SNR). Today, the Shannon-Hartley theorem does not account for the effect of multiple spatial streams on total data throughput – but it does illustrate the direct correlation between channel bandwidth and data rate.

In an OFDM system, one can intuitively understand the correlation between wider bandwidth and higher data rates. For example, consider the fact that when the same subcarrier spacing is maintained (and hence symbol rate), adding more subcarriers inherently requires increasing the channel bandwidth. In the 802.11ac specification, the relationship between channel bandwidth and number of data subcarriers can be clearly observed. As shown in ***Table 2***, the subcarrier spacing is fixed in all bandwidth modes and that bandwidth is increased simply by increasing the number of subcarriers.

The optional 160 MHz mode marks a substantial change from the maximum bandwidth supported by 802.11n (40 MHz). Today, the only Wi-Fi band with 160 MHz of available spectrum occurs in the 5 GHz band (and not in the 2.4 GHz band) and thus, the 802.11ac specification applies only to the 5 GHz ISM band.

INCREASING SPATIAL STREAMS

While the Shannon-Hartley theorem is able to reasonably estimate the maximum theoretical throughput in a Single Input Single Output (SISO) channel, it must be slightly modified to adequately predict the maximum channel throughput in a MIMO channel. In a physical channel with sufficient multipath reflections, the maximum theoretical improvement in data rates scales linearly with the number of theoretical spatial streams. For example, in a 2×2 MIMO system, the use of two independent spatial streams in the same physical channel, (that is at the same frequency), effectively doubles the data rates over what one might expect from a traditional SISO system. Accordingly, a 4×4 MIMO channel would enable 4× data rates improvement and an 8×8 MIMO channel would enable 8× data rates over a SISO channel. As such, a modified version of the Shannon-Hartley theorem can be illustrated. Similar to other emerging wireless specifications, such as 3GPP's LTE Advanced, 802.11ac VHT specification allows for use of up to 8×8 MIMO.

TABLE II

CHANNEL BANDWIDTH OPTIONS IN 802.11AC

Channel Bandwidth (MHz)	Subcarrier Spacing (kHz)	Total Subcarriers (IFFT Size)	Data Subcarriers	Pilot Subcarriers
20	312.5	64	52	4
40	312.5	128	108	6
80	312.5	256	234	8
160*	312.5	512	468	16

** Denotes this mode is optional for 802.11ac*

TABLE III

EVM TRANSMITTER MINIMUM PERFORMANCE REQUIREMENTS

Modulation	Coding Rate	RMS EVM
BPSK	1/2	-5 dB
QPSK	1/2	-10 dB
QPSK	3/4	-13 dB
16 QAM	1/2	-16 dB
16 QAM	3/4	-19 dB
64 QAM	2/3	-22 dB
64 QAM	3/4	-25 dB
64 QAM	5/6	-27 dB
256 QAM	3/4	-30 dB
256 QAM	5/6	-32 dB

ENHANCEMENTS IN MODULATION SCHEME AND CODE RATES

Perhaps one of the most interesting mechanisms offered by 802.11ac to increase data throughput is the use of the 256 QAM modulation scheme. Since the deployment of 802.11a, the 64 QAM modulation type was considered the "highest order" modulation type among all wireless standards. However, 802.11ac marks the first major commercial wireless standard in the consumer world that invokes 256 QAM for increased data throughput. Equation 2 shows the simple relationship between the "order" of a modulation scheme and the number of bits that can be represented by each individual symbol.

$$\text{Bits Per Symbol} = \log_2(\text{Modulation Order}) \quad (2)$$

It shows how simple modulation schemes, such as Binary Phase Shift Keying (BPSK) which utilizes only two symbols, would produce only one bit per symbol ($\log_2(2) = 1$). By contrast, a more complex modulation scheme, such as 256 QAM, is considered to have a higher "order" and thus produce higher data rates. In fact, 256 QAM yields eight bits per symbol ($\log_2(256) = 8$). By comparing 802.11ac to 802.11n, it can be seen that, in environmental conditions where 256 QAM can be sustained, up to 33 percent higher data rates over the traditional 64 QAM scheme would be enabled.

One interesting note on modulation order is that a very tight correlation between the modulation quality of a transmitter and the Shannon-Hartley theorem is shown. One of the easiest ways to observe this relationship is to look at the 802.11ac specification limits for transmitter relative constellation error (equivalent to EVM). As shown in ***Table 3***, higher-order mod-

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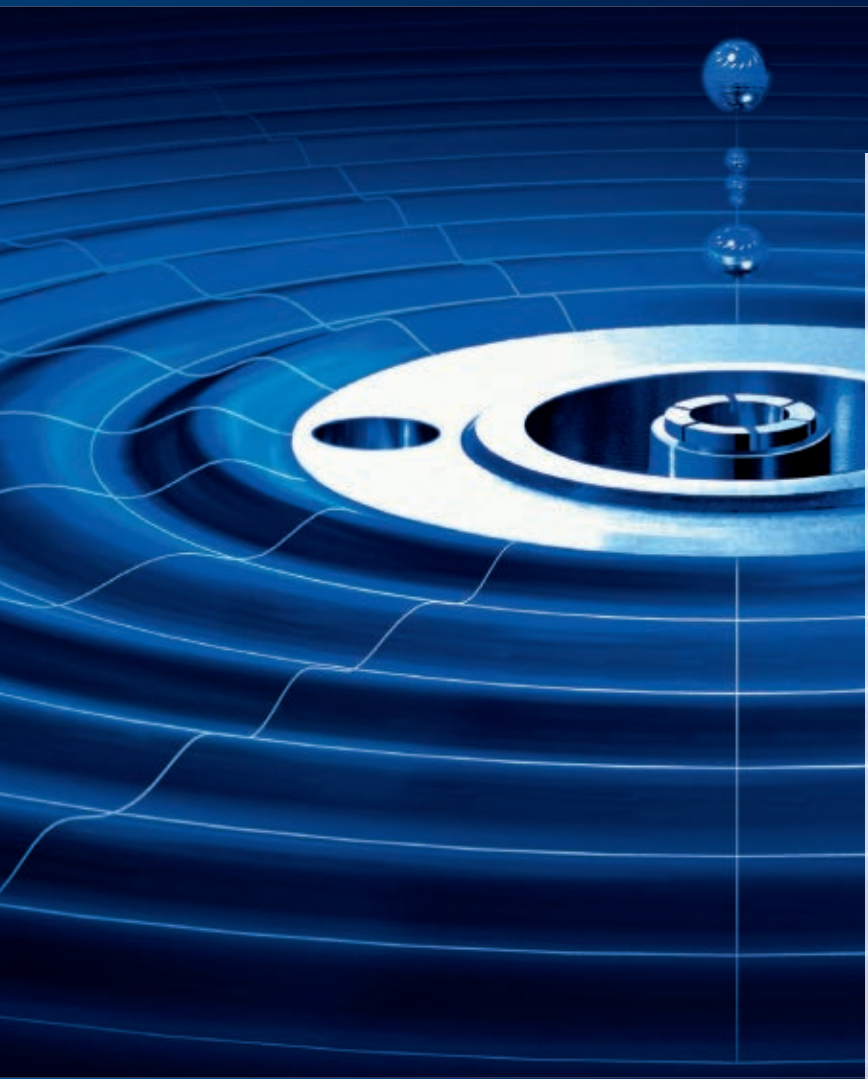

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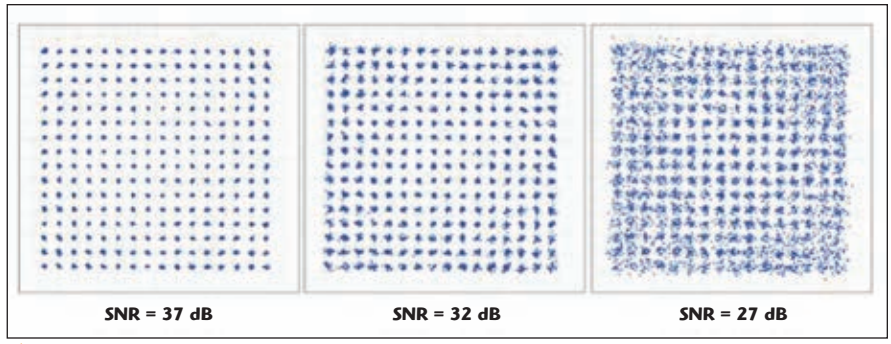

Fig. 1 Higher SNR enables use of higher modulation types, such as 256 QAM.

ulation types such as 256 QAM, have more stringent EVM requirements – not surprising given there is very close correlation between EVM and SNR.

In order to best illustrate the effect of SNR on the order of modulation type, ***Figure 1*** illustrates the constellation diagram of a 256 QAM signal in various SNR environments. As shown in the constellation diagram for 256 QAM, an SNR of 32 dB is sufficiently large to demodulate a 256 QAM signal without significant bit errors – and, hence, frame errors. By contrast, in an environment with a lower signal-to-noise ratio, a smearing in the constellation occurs, which is evident at an SNR of 27 dB or less. Under these channel environment conditions, a given Wi-Fi access point would not be able to sustain communications using 256 QAM, but would transition to a lower-order modulation scheme that was capable of sustaining the appropriate frame error rate performance. This example is a practical illustration of the relationship between SNR and data throughput as described in the Shannon-Hartley theorem.

CALCULATING DATA RATES

Given the key enhancements in the 802.11ac specifications, such as wider bandwidth, more spatial streams and higher-order modulation types, one would suspect that the optional high throughput features would yield roughly an order of magnitude higher data rates than 802.11n. In fact, with the theoretical limits for 802.11n at approximately 600 Mbps, the data rate increase in 802.11ac should roughly be an order of magnitude higher.

In order to correctly predict the maximum theoretical throughput of 802.11ac, key factors, such as modulation type, number of data subcarriers, code rate, symbol rate and number of spatial streams, must be considered. To determine the aggregate data rate, first determine the number of coded data bits that can be transmitted at any one time. The pre-draft 802.11ac specifications refer to this as the "Number of data bits per subcarrier" (N_{DPSC}) and it includes data bits over all spatial streams. Mathematically, N_{DPSC} is determined by factors such as the bits per symbol, code rate and number of data subcarriers. Mathematically, N_{DPSC} can be represented by

$$N_{DPSC} = \text{Bits Per Symbol} \times \text{Number of Data Subcarriers} \times \text{Code Rate} \quad (3)$$

For example, in a 20 MHz 802.11ac transmission, 52 of the 64 subcarriers are used for data and the rest are used for a combination of guard bands, null subcarriers or pilot tones. If one were to use a modulation type of QPSK and a code rate of ½, N_{DPSC} would equal 26 bits (1 × 52 × 0.5). In ***Table 4***, N_{DPSC} is computed for a number of combinations of bandwidth and spatial streams, for scenarios where the 256 QAM modulation type is used.

Given the total data bits per spatial stream, the maximum theoretical throughput of the 802.11ac physical layer can be calculated simply by multiplying N_{DBPS} by the number of spatial streams, the symbol rate and percentage of total symbol period that is utilized for data. In this case, the symbol rate is equivalent to the subcarrier spacing, which is 312.5 kHz or 312,500 symbols/second. This relationship is illustrated in Equation 4.

$$\text{Data Rate} = N_{DEPS} \times \text{Symbol Rate} \times \frac{T_{DFT}}{T_{SYM}} \quad (4)$$

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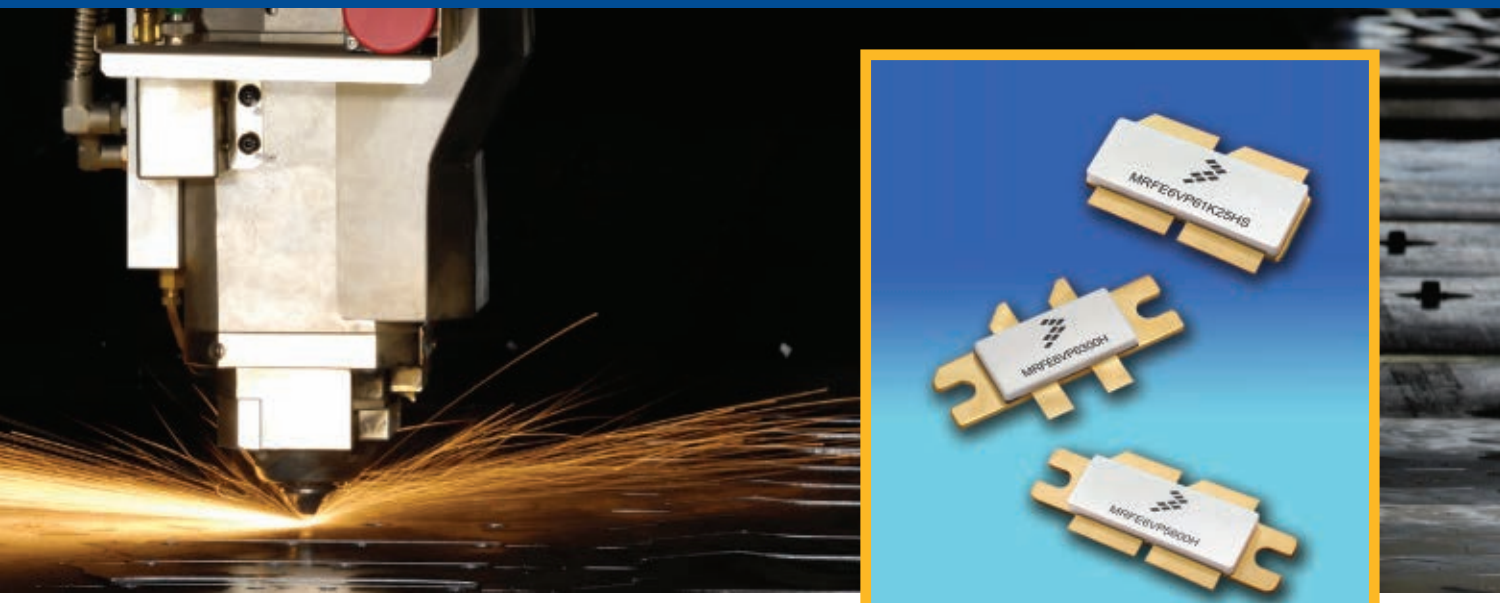

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TABLE IV
N_{DPSC} AND DATA RATE INCREASES EXPONENTIALLY WITH INCREASE IN BANDWIDTH AND SPATIAL STREAMS

Channel Bandwidth (MHz)	Spatial Streams	Modulation Scheme	Code Rate	Total Subcarriers	Data Subcarriers	N_{DPSC}	Max. Data Rate
20	1	256 QAM	3/4	64	52	312	86.7 Mbps
40	2	256 QAM	5/6	128	108	1440	400 Mbps
80	4	256 QAM	5/6	256	234	6240	1.7333 Gbps
160	8	256 QAM	5/6	512	468	24960	6.933 Gbps

** Denotes this mode is optional for 802.11ac*

As Equation 4 demonstrates, the symbol utilization is the ratio of the data symbol period divided by the total symbol interval. Where:

T_{DFT} = DFT/IFDFT Symbol Period = 3.2 µs

T_{SYMS} = Short GI symbol interval = 3.6 µs

T_{SYML} = Long GI symbol interval = 4.0 µs

Thus, in configurations where the short guard interval is used, the utilization is 3.2/3.6 = 88.9 percent. Similarly, when the long guard interval is employed, the utilization is 3.2/4.0 = 80 percent.

The maximum theoretical throughput of an 802.11ac communications channel can be now be estimated. In determining the maximum theoretical throughput for 802.11ac, 8×8 MIMO, 160 MHz channel bandwidth, 256 QAM modulation scheme and the short guard interval are used. In this case, the theoretical maximum data rate is shown in Equation 5.

$$\text{Data Rate} = 24960 \text{ bits} \times 3125000 \frac{\text{Sym}}{\text{sec}} \times \frac{3.2\,\mu\text{s}}{3.6\,\mu\text{s}} = 6.933 \text{ Gbps} \quad (5)$$

The theoretical maximum data throughput offered by the 802.11ac physical layer is greater than 6.9 gigabits per second. However, it must be noted that this approximation is merely a theoretical calculation. In practical terms, data rates exceeding 6.9 Gbps are only possible when the physical channel is physically diverse enough to allow for eight spatial streams simultaneously. Moreover, given the SNR requirements on the 256 QAM modulation types, it is likely that the maximum theoretical throughput will only be approached in scenarios where the transmitter and receiver are in close proximity – where signal strength will be much higher. Finally, it must be also realized that there is much more to a communication system than just the physical layer. While it is clear that the physical layer should be able to support 6.9 Gbps, substantial enhancements must also be made to the MAC layer, digital data buses and even embedded processors in order for vendors to produce products capable of utilizing the maximum data throughput.

THE CHALLENGE OF 802.11AC TESTING

The next generation of wireless standards, such as 802.11ac, produces obvious benefits to consumers in the form of higher data rates. However, design and test of the radios designed to use these standards pose significant test challenges. For example, today's engineers have to deal with the complexity of multi-radio testing configurations such as 8×8 MIMO. In addition, the bandwidth requirements of the optional 160 MHz specification are substantial and engineers will be tasked with obtaining good measurement fidelity over increasingly wider bandwidths. Finally, in automated use cases, measurement speed often increases with measurement complexity. Given that, demodulation of 802.11ac signals requires an order of magnitude more of signal processing power. Measurement speed associated with 802.11ac testing will also be a concern. Going forward, it appears that software-defined PXI test equipment will be at the forefront of testing next generation standards. Today, 802.11ac products are already being tested with PXI test equipment and the core benefits of PXI, such as modularity, flexibility and signal processing power, will continue to drive PXI adoption in the test and measurement industry in the near future. ■

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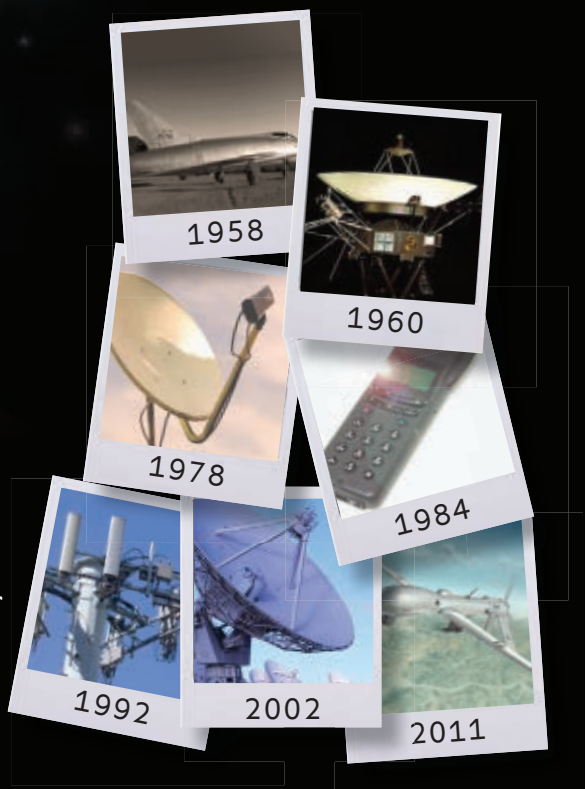

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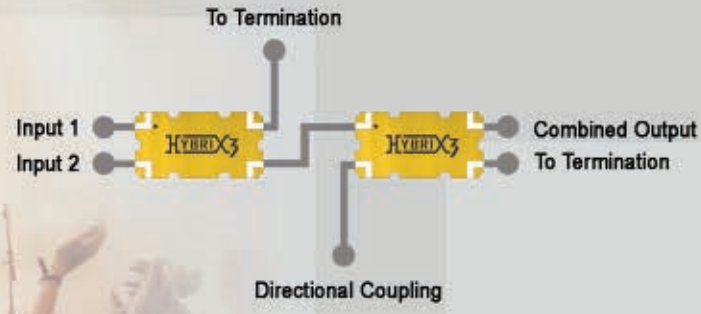
The Doupler™

Half the Insertion Loss - Single Package

Previous Implementation

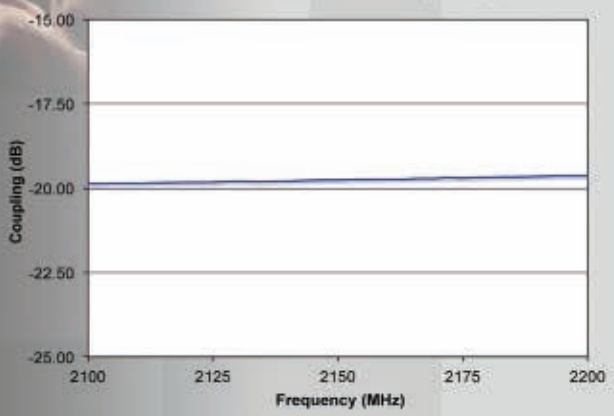


Doupler Implementation

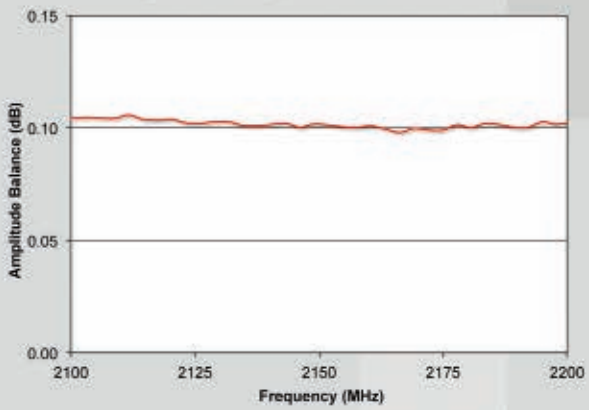
Typical In-band Performance

Insertion Loss	Directivity	Power Handling	Hybrid Coupling	Directional Coupling
0.2 dB	20 dB	200 W	3 ± 0.15 dB	20 dB

Directional Coupling



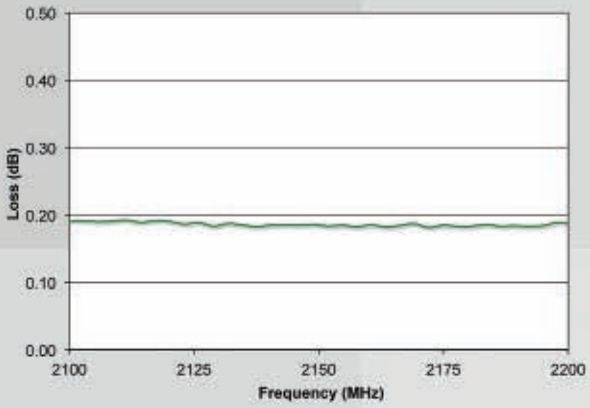
Hybrid Amplitude Balance



Power Combining Applications:

UMTS	Part Number: DHDL20F
PCS	Part Number: DHDJ20F
GSM 1800	Coming January 2012
WGSM	Coming January 2012
CDMA	Coming February 2012
LTE	Coming February 2012

Doupler Insertion Loss



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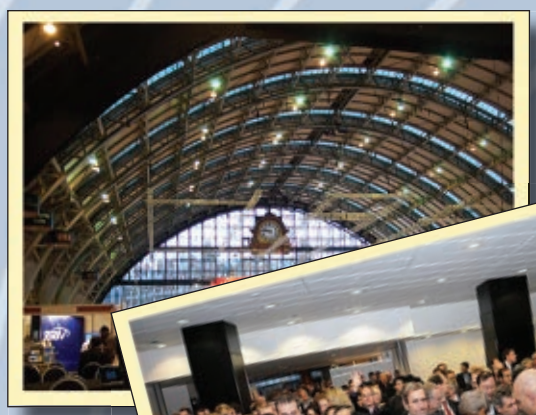
EuMW 2011 Wave to the Future

The largest microwave conference and exhibition outside of North America was held in Manchester, UK, from October 9th to the 14th. View videos and read all about the technical conferences, special defence & security forum and vendor product news at mwjournal.com.

Show Wrap-up by the Numbers



4732 attendees, comprising delegates, exhibitors and visitors

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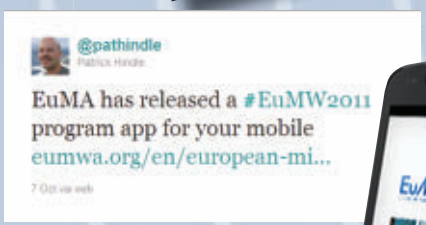


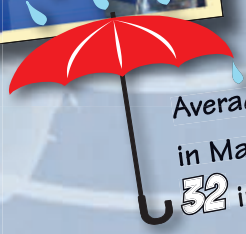
Mobile downloads: **250**

MWJ/EuMW Videos Online:

- **4** EuMW interviews
- **10** T&M demos
- **4** component demos
- **3** conference highlights
- **6** defence and security forum segments

252 exhibiting companies

5800 square meters of gross exhibition space



Average Annual Rainfall in Manchester **32** inches

Asia: **10%**

North America: **30%**

Europe: **60%**

up to **300** liters of beer consumed per capita in the UK

MWJ Online Page Views

Defence and Security Forum: **2884** Online Show Coverage: **1254** Show Wrap-up: **1104**

1000 papers submitted from over **50** countries. **375** papers were presented in technical sessions, **200** in posters and **195** in workshops and short courses.

For the complete wrap-up, visit mwjournal.com/eumw2011wrap-up


Manchester Evening News

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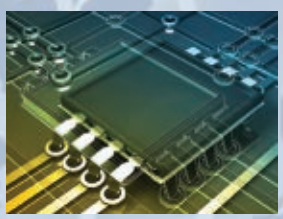
M.E.N.

UK Government forms £50 million Global R&T for Graphene

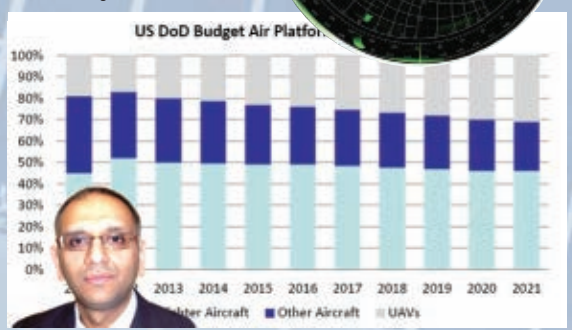


RF Semiconductors and ICs

Over **100** technical papers, **27** total sessions, **13** workshops and **2** short courses. Plus a look at foundry services with UMS, OMMIC, GCS Inc., TriQuint Semiconductor and WIN Semiconductors.

2010 Nobel Laureate- University of Manchester Prof. K. S. Novoselov opened EuMW with a keynote on graphene and future electronics.

364 registered attendees at the **EuMW Defence and Security Forum**



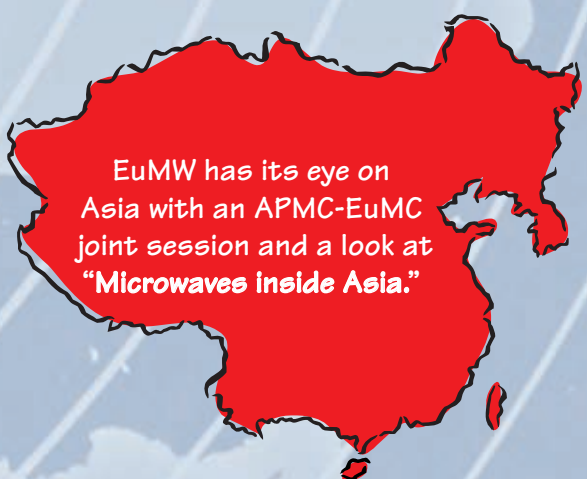
UAV Growth in Overall US DoD Air Platform Budget **20%** to **31%**

Market Research from Asif Anwar, Strategy Analytics

Radars

Over **80** papers, organized into **19** sessions, covering four main areas: radar subsystems and phenomenology, signal processing, architectures and systems, and applications, complemented by **35** poster papers.

Read MWJ wrap-up



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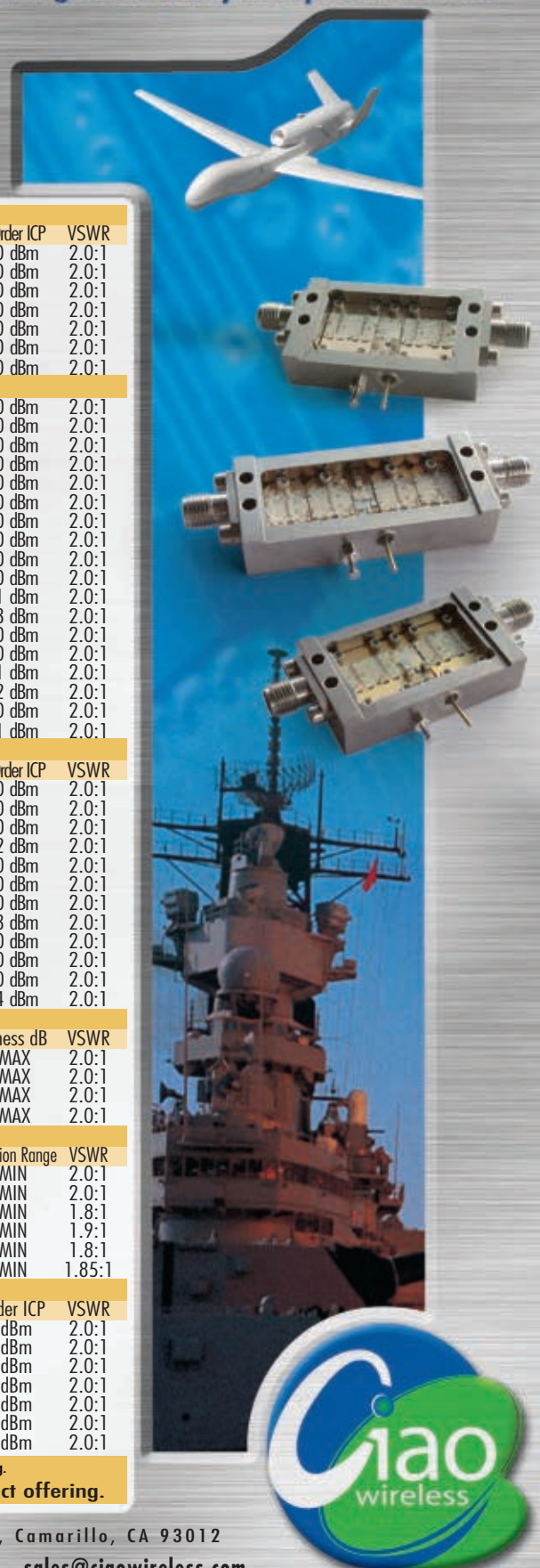

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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US Army Awards SRC $9 M Contract for OWL Radar Prototype Development

The US Army's Intelligence and Information Warfare Directorate has awarded a contract to SRC Inc., formerly Syracuse Research Corp., for the development of an Omni-Directional Weapon Location (OWL) radar system. The contract includes a 32-month award valued at approximately $9 M. Under the terms of this contract, SRC will develop the OWL system design and produce a technology demonstrator prototype to be evaluated in 2013.

"We are extremely proud of this contract award for OWL, as it is further evidence of our leadership in radar development. The innovative design and technological advances of the OWL system will provide an impressive capability for the Army," said Paul Tremont, President of SRC. "For more than 50 years, SRC has been committed to keeping America safe and strong, and our mission continues to drive our motivation to create systems that save lives, like the OWL radar."

The OWL radar will be a state-of-the-art, yet affordable, weapon location radar system, providing the Army with the ability to detect, track and locate mortar, cannon and rocket firing positions with unprecedented accuracy over a wide variety of threat trajectories. OWL is a multi-mission-capable system that provides surveillance over a hemispherical coverage area.

In response to the contract award, Sen. Charles E. Schumer stated, "We know our highly skilled workforce can compete amongst the best of the best and win. SRC's award reaffirms central New York's commitment to innovating and succeeding in the highly competitive defense industry and their work with the OWL radar contract will keep our service members safe, our local workforce on the job and our nation protected."

"For more than 50 years, SRC has been committed to keeping America safe and strong."

US Sen. Kirsten Gillibrand said, "The Army's decision to award this important contract to SRC is direct testimony to the outstanding work this New York company is doing, especially in the area of advanced radars. The OWL radar system will not only strengthen a terrific local company, but the system will ensure the safety of our troops."

Congresswoman Ann Buerkle also lauded SRC.

"I would like to congratulate SRC on this award in support of the OWL program," she said. "SRC's continued growth and expansion is good news for the central New York economy and for ongoing efforts to advance this region as a top location for high tech businesses and research and development."

SRC is known for its high tech development capabilities, such as its Lightweight Counter-Mortar Radar, which was named Army's "Top Ten Greatest Inventions." In addition, SRC has successfully developed and tested other systems, including the Army's enhanced Multi-Mission Radar, Defense Advanced Research Projects Agency's FORESTER foliage penetration radar and the Army's Advanced Ground Electronic Warfare System.

Northrop Grumman to Complete Advanced Technology Microwave Sounder for NASA

Northrop Grumman Corp. will build and deliver the Advanced Technology Microwave Sounder (ATMS) for the Joint Polar Satellite Systems (JPSS) under a contract with NASA. JPSS is a system of polar-orbiting satellites to be developed by NASA for the National Oceanic and Atmospheric Administration (NOAA) for weather forecasting, storm tracking and climate monitoring. The ATMS instrument is the second flight model and is slated to fly on the first JPSS satellite in 2016. The first ATMS was completed in 2005 and has been integrated on the NPOESS Preparatory Project (NPP) satellite, which is scheduled to launch in October.

"The successful contract transition is an important milestone for the Joint Polar Satellite Systems, since ATMS is one of its key operational weather sensors," said Dr. Steve Toner, Vice President of Northrop Grumman's Overhead Persistent Infrared and Azusa Programs business unit. "The Flight 2 development, build and test have proceeded smoothly and follow the success of the Flight 1 instrument for NPOESS Preparatory Project."

ATMS will provide critical microwave data, including atmospheric temperature and moisture profiles, to support weather forecasting for the operational JPSS system. The instrument has 22 channels spanning the frequency band from 23.8 to 183.3 GHz. It was designed to be the functional equivalent follow-on to the Advanced Microwave Sounder Units with improved sampling and coverage.

"ATMS is one of (the Joint Polar Satellite Systems') key operational weather sensors."

"Our experience in creating the ATMS engineering development unit and delivering the NPOESS Preparatory Project flight unit showed our capability to support the customer," said Steve Opel, ATMS Program Manager at Northrop Grumman. "This transition of the second flight unit to the Joint Polar Satellite Systems not only capitalizes fully on that previous experience, but also demonstrates our commitment to developing a long-term partnership with both NASA and NOAA on this program."

Go to www.mwjournal.com for more defense news items

Raytheon Installs Cobra Judy Replacement's X- and S-Band Antennas

Raytheon Co. has completed the shipboard installation of the Cobra Judy Replacement program's X- and S-Band antennas onto the USNS Howard O. Lorenzen (T-AGM 25). These massive active phased-array antennas, each weighing more than 500,000 pounds, were installed onto the ship at Kiewit Offshore Services (KOS), Corpus Christi, TX.

"This is a significant chapter in Raytheon's extensive legacy in large-scale active phased-array radars," said Raytheon Integrated Defense Systems' (IDS) Kevin Peppe, Vice President of Seapower Capability Systems. "The Cobra Judy Replacement program marks the first shipboard integration of a true dual-band active phased-array radar suite – a major milestone for both the US Navy and our industry team."

The mission of the CJR program is to provide the government with long-loiter ballistic missile data collection capability. Its dual-band radar suite consists of X- and S-Band phased-array sensors, a common radar suite controller and other related mission equipment. All of CJR's mission equipment has now been installed onto the ship, and Raytheon is proceeding with shipboard dual-band radar integration and testing per the program plan.

Raytheon is the prime contractor for the CJR mission equipment and principal on an industry team that includes Northrop Grumman Electronic Systems, General Dynamics SATCOM Technologies, VT Halter Marine and KOS. The team has been a model of collaboration, focused on the delivery of a high performing shipboard radar capability that the US Navy can rely upon as a critical fleet asset.

"This is a significant chapter in Raytheon's extensive legacy in large-scale active phased-array radars."

Prior to installation onboard the Lorenzen, the X-Band and S-Band arrays were installed and integrated into their enclosures. Raytheon also successfully simulated the processing of dual-band data through the common back-end as it was installed. The common back-end is the core integration technology that coordinates the two radars. All of the ship's major hardware has now been installed.

Work on the CJR program is primarily performed at Raytheon IDS' Surveillance and Sensors Center, Sudbury, MA; Northrop Grumman Electronic Systems, Baltimore, MD; and Kiewit Offshore Services. The T-AGM 25 ship was built for the Navy by VT Halter Marine, Pascagoula, MS.

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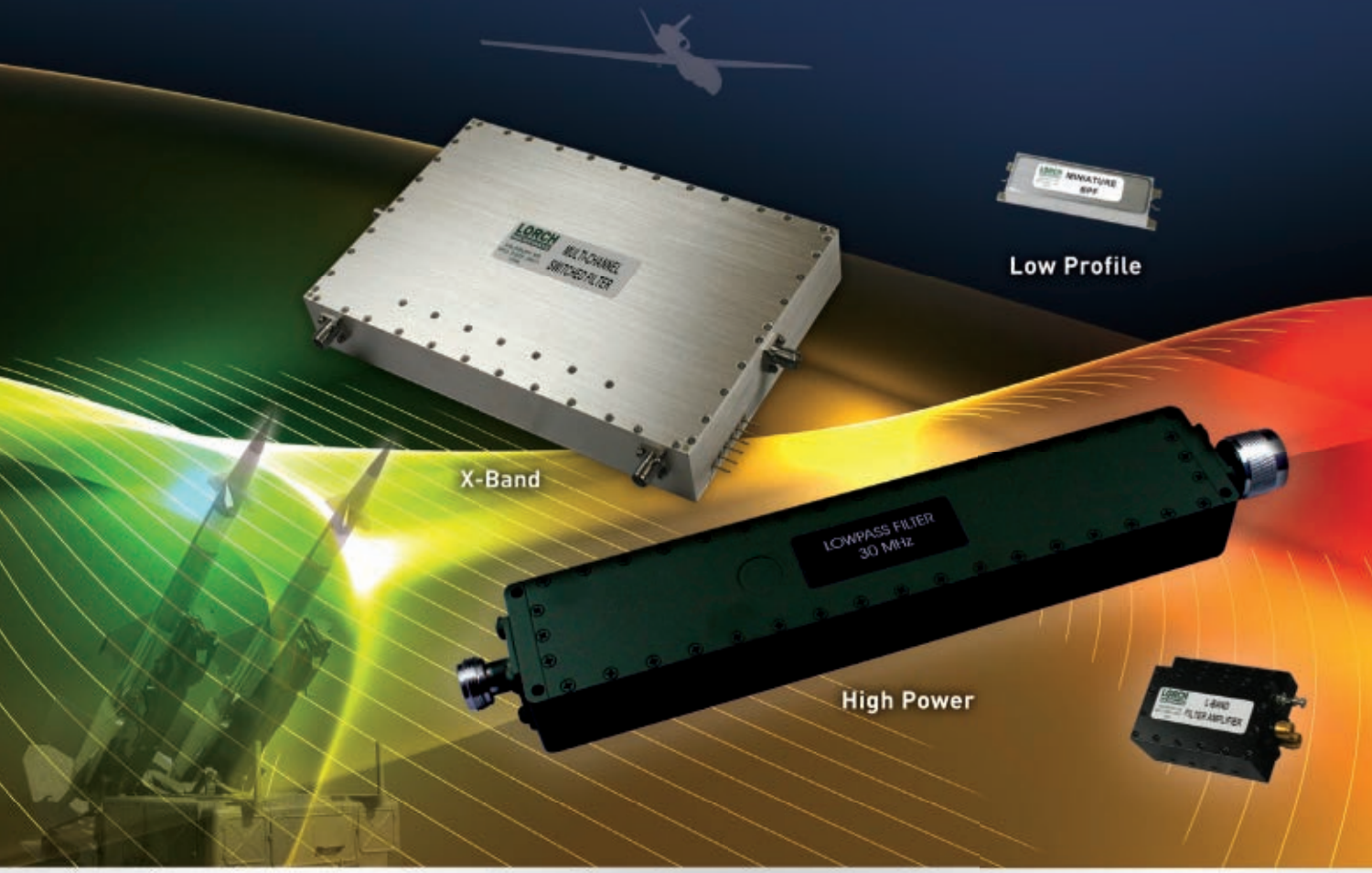

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Chalmers Team Uses Microwaves to Fight Tumours, Detect Breast Cancer

A research team from Chalmers University of Technology, Gothenburg, Sweden, has developed two new techniques of cancer diagnosis and treatment with the aid of microwaves. One method is an alternative to mammography that uses X-rays to detect breast cancer. The other method aims to treat tumours in the head and neck by heating the cancer cells.

Andreas Fhager, Associate Professor of Biomedical Electromagnetics at Chalmers, has developed a system to detect breast cancer with a new technique known as microwave tomography. Fhager's "microwave tomograph" currently consists of some 30 antennas arranged around a cylindrical container adapted to the breast. All antennas act both as transmitters and receivers. The microwaves spread out in a complex pattern that is analysed by advanced algorithms, which reconstruct an image of the breast tissue in 3D.

"We obtain three-dimensional images showing significantly better contrast between healthy and malignant tissue compared to X-rays," Fhager explained. "That makes it easier to detect even really small tumours that may currently be obscured by healthy tissue, thus creating the preconditions for much more reliable diagnosis. Unlike X-rays, the technique also emits negligible doses of non-ionising radiation – less than a hundredth of the radiation to which you are exposed when talking on a mobile phone."

In the second Chalmers project, the microwaves are used to destroy the tumours by heating them, a process known as hyperthermia. Antennas transmit microwaves with high efficiency, perfectly synchronised to heat up individual tumours. Clinical studies have shown that treatment with conventional radiotherapy and chemotherapy in combination with hyperthermia may double the long-term ability to cure certain forms of cancer, such as cervical cancer and soft-tissue sarcoma.

"We are now developing a new hyperthermia system that can reach deep-seated tumours in the head and neck with high accuracy," said Hana Dobšíček Trefná, who holds a doctorate in biomedical engineering. "In this way, higher temperatures can be reached in the tumour without affecting the surrounding tissue."

With time, the Chalmers team hopes to be able to combine both methods. As soon as a tumour is detected, the already connected antennas could be used to start treating the tumour directly while at the same time monitoring that the right tissue is heated up. The method should also be applicable for parts of the body other than breasts, head and neck. Theranostics – the treatment and diagnosis of diseases in a single system – is a growing area of research, and the Chalmers team believes that microwaves have great potential in the field.

Research Team Claims First Tunable Broadband Photonic Phase Shifter

A team of researchers from the Universitat Politècnica de València's El Instituto de Telecomunicaciones y Aplicaciones Multimedia (iTEAM) in Spain claims to have created the first tunable broadband RF photonic phase shifter. The study was funded in part by the "Governing the speed of light" (GOSPEL) project, which was backed under the Information and Communication Technologies (ICT) theme of the EU's Seventh Framework Programme (FP7) to the tune of €2.19 M.

Experts believe optical phase shifters for RF signals are important components for the installation of hybrid broadband telecommunication systems. They combine fibre optic transmission and radio transmission. They are the basis of convergence between networks, a required step for either accessing the Internet or swapping the orientation of radar and satellite antennas.

They are…a required step for either accessing the Internet or swapping the orientation of radar and satellite antennas.

According to the researchers, there are several applications of the phase shifter, including radio astronomy and terrestrial satellites, as well as radar antennas, ultra wideband communications, radio link systems and RF applications for automobiles. These applications help boost the flow of information transmission, effectively mitigating traffic and guaranteeing the best performance of the entire communication system.

José Capmany, the head of UPV's iTEAM, said the phase shifter is important for two reasons.

"First, a 75 percent reduction – in comparison with previous designs – in the number of components needed will make it possible to save some of the space that the phase shifter occupies when it is integrated into a chip, and, consequently, save in the production costs too," he said. "Moreover, reducing the number of active elements from five to one means a saving in energy consumption of up to 80 percent."

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European Research Council Grants to Take Projects from Research to Market

A series of European Research Council (ERC) "top up" grants worth up to €150,000 each have been awarded to 30 leading researchers across Europe. Part of the ERC's new "Proof of Concept" funding initiative, these grants are being awarded to researchers who already hold ERC grants, in order to help them transform their ideas into marketable innovative solutions. The idea is to help researchers package their ideas and demonstrate commercial potential so as to appeal to potential investors.

The ERC is the first European funding body set up to support investigator-driven frontier research. Its main aim is to stimulate scientific excellence by supporting and encouraging the very best, truly creative scientists, scholars and engineers to be adventurous and take risks in their research. The scientists are encouraged to take an innovative approach.

ERC President Professor Helga Nowotny commented, "The Proof-of-Concept scheme has been set up to provide a bridge for ideas emerging from frontier research that might be attractive for markets. Innovation takes place in companies. We offer to ERC grantees the possibility to probe and prove the innovative potential of their ideas and we trust that many of them will find their way to be transformed into productive outcomes."

EADS and RUSNANO Join Forces on Nanotechnology Research Programmes

European aerospace and defence group EADS and Russian Nanotechnology Corp. RUSNANO have signed a cooperative research and development agreement in the field of nanotechnology. As a first step, the partners will identify relevant patents in EADS's portfolio, which could be suited to develop new business in the Russian industry.

"As a global leader in aerospace and defence, EADS has technologies that can help our partners maintain their competitive edge," EADS CTO Jean Botti said. "Today's agreement establishes the ground for cooperation in different areas through the use and transfer of Intellectual Property and technology. We are pleased to partner with RUSNANO, a corporation at the forefront of innovation in Russia."

"The advanced technologies of EADS complement well with RUSNANO's strong position in the Russian high tech market," stated RUSNANO CEO Anatoly Chubais. "Our cooperation paves the way for progress in nanotech-related fields, including energy efficiency, new materials, life science and security."

In 2003, the company established a Russian Technology Office, which has been involved in more than 100 cooperative research and technology programmes between EADS and Russian institutions.

TINY

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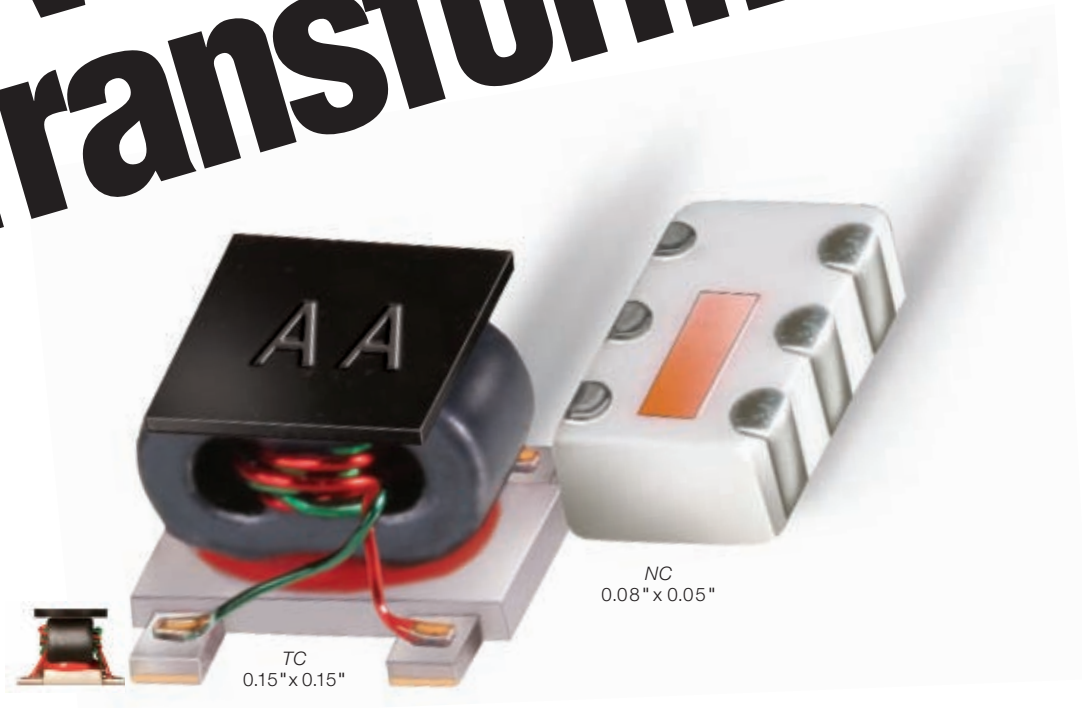

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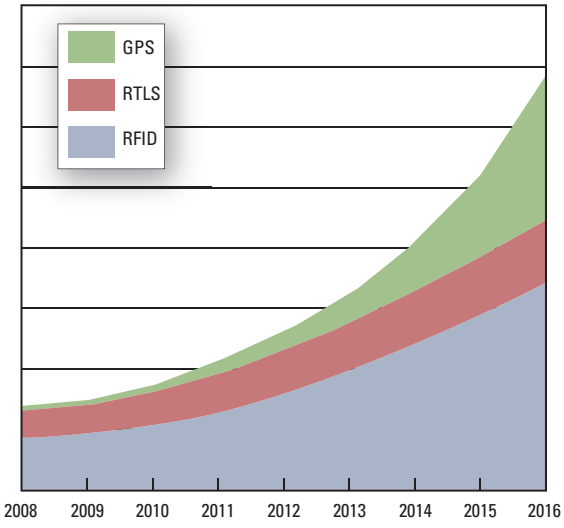
Container Shipping Market to Boost Security and Tracking Revenues

Container security and tracking revenues will grow at a compound annual growth rate (CAGR) of 27 percent from $212 M in 2011 to $690 M in 2016, according to ABI Research.

"With a lot of regulations and legislation being introduced in the aftermath of 9/11, expectations that this industry would finally take off were high, prompting many vendors to enter this market with advanced solutions," said Dominique Bonte, ABI's Telematics and Navigation Group Director. "While RFID-based point solutions at port yards are becoming more established – at least in North America and Western Europe – uptake of more advanced GPS-based solutions has been disappointing, despite several solutions having been made available by vendors such as SkyBitz, DB Schenker, Starcom, and Pointer Telocation – mainly for the intermodal market."

ABI's "Cargo Container Security and Tracking" study covers maritime and intermodal asset management solutions that are enabled with a family of integrated wireless technologies to provide real-time, global tracking, security and communications features. It includes detailed descriptions of segments and verticals, applications and functionality, market drivers and barriers, regulation, and legislation, as well as shipment and revenue forecasts.

Total Container Security and Tracking Revenues by Technology
World Market, Forecast 2008 to 2016



Source: ABI Research

WSN Chipsets for the Industrial Automation Market Will Hit $8 M in 2016

In 2010, global spending on wireless sensor networking (WSN) chipsets in industrial automation reached $2 M, with the overall market expected to grow to $8 M by 2016, according to ABI Research. Industrial automation consists of two market segments, process automation and factory automation, in which WSN in field devices has seen broader adoption in the former, particularly in the realm of monitoring. Key adoption is seen in monitoring applications, such as oil refineries, petrochemical plants to facilitate plant operation efficiencies, safety prevention, and compliance, alongside asset management.

Two industrial WSN protocols that are based on IEEE 802.15.4 silicon, WirelessHART and ISA100.11a, have been the driving force behind WSN adoption in process automation. WirelessHART, leveraging on an estimated installed base of 30 million HART devices, has the largest addressable market for WSN deployment. This is aided further with its ratification as IEC 62591 in 2010, reassuring end users contemplating the deployment of standardized devices.

"WIA-PA should see significant potential within China."

"After WirelessHART, a competing industrial WSN protocol, ISA100.11a, which is geared toward interoperability with a multitude of industrial protocols, is next in line to see wide adoption, albeit with a higher growth potential," said Kelvin Chan, Industry Analyst, M2M and Smart Energy.

A third emerging protocol, WIA-PA, which is also based on IEEE 802.15.4 silicon, is undergoing standardization and will become a Chinese national standard.

"Considering China's market size by sheer size, scope, and level of manufacturing, WIA-PA should see significant potential within China, but it is unlikely to extend its reach across the globe without broader standardization efforts and support from manufacturers outside of China," Chan said.

ABI Research's study "Industrial Wireless Sensor Networks" analyzes the market opportunity for WSN in industrial deployments; the implications of the key standards efforts including WirelessHART, ISA-100.11a, and WIA-PA; the implications WSN adoption will have for the market; and the key players involved in making WSN a reality in industrial automation.

80 Million LTE Connections Seen by 2013

By the end of 2013, LTE connections will be close to 80 million, according to ABI Research. This figure will account for connections on both FD-LTE, including that paired with W-CDMA/HSPA and CDMA 1x/EV-DO, and TD-LTE technologies globally.

"We are expecting to see more LTE networks lighting up in the next year or two, but operators are now taking a quieter approach when it comes to deployment," said Fei Feng Seet, Research Analyst, Wireless.

This is evident in the case of Saudi Arabia, where all three of the nation's operators, Mobily (Etihad Etisalat), Saudi Telecom Co. (STC) and Zain Saudi Arabia an-

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nounced their LTE network launches within a matter of days of one another. All three fought hard to gain recognition and have first mover advantage in the Middle East. The interesting part is that all three are rolling-out TD-LTE networks using 2.5 GHz licensed spectrum meant for WiMAX and plan to extend their coverage nationwide. While the Saudi operators have conducted FD-LTE trials for over a year with various vendors, the reason behind the TD-LTE network choice is primarily due to unavailable paired spectrum. They are waiting on the regulator to release new spectrum, since preferred frequency is currently used for military purposes.

"The issue of insufficient spectrum echoes across various markets and is especially evident in developing regions as regulators are a bit slow in reacting to market needs," said Philip Solis, Research Director, Mobile Networks.

Many operators are looking into the option of spectrum re-farming. While the preferred spectrums are usually 2.6 GHz or 700 MHz, players such as Poland's Aero2 and Singapore's MobileOne have successfully deployed FD-LTE on 1.8 GHz, which was slated for 3G usage. Aero2 has deployed TD-LTE on 2.5 GHz band. Reacting to operator demand, both TD-LTE and FD-LTE devices are expected to flood the market in the next few years driving subscriber connectivity. ABI Research's "4G Subscriber, Device, and Networks Market Data" contains regional and selected country-level segmentation for the 4G market, including forecasts for mobile WiMAX and LTE subscribers, devices, base stations, and population coverage.

Multiple Secure Elements to Drive NFC Market Above $1 B in 2016

Out of a total of 552 million NFC handsets shipped in 2016, 227 million will feature multiple secure elements. The increased inclusion of multiple secure elements will drive the mobile NFC market valuation above the $1 B mark. Although MNOs favor SWP SIM implementation, the market will develop with both SWP and embedded solutions shipping onto single devices. Continued development of ICs combining both controller and secure element will result in most handsets shipping with an embedded solution as standard practice. ABI Research forecasts that 78 percent of all NFC handsets will ship with some form of embedded secure solution in 2016.

"The issues affecting the location of the secure element remain a hot topic and, although progress has been made, there remains uncertainty among ecosystem players," said Research Analyst Phil Sealy.

As the market matures and business models are realized and deployed, a variety of secure elements are being deployed into devices to meet different client demands. In the long run, this will allow service providers to enter the NFC market alongside MNOs, in turn making the offerings of NFC applications more competitive. As well as the well-publicized NFC handset market, lesser known sectors, such as CE devices, tags, bridging solutions, and other markets will account for additional IC shipments totaling 534 million in 2016.

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Kerri Germani, Staff Editor

INDUSTRY NEWS

Microsemi Corp., a leading provider of semiconductor solutions differentiated by power, security, reliability and performance, and **Zarlink Semiconductor Inc.** announced that 0916753 B.C. ULC, an indirect wholly owned subsidiary of Microsemi, has accepted the tender of and is acquiring 123,438,737 Zarlink shares, representing approximately 96 percent of Zarlink's outstanding shares, and CAD $54,417,000. With the success of this tender, Microsemi takes control of Zarlink's board and operations.

AMETEK Inc., a manufacturer of electromagnetic compatibility (EMC) test equipment, has acquired the parent company of **EM Test (Switzerland) GmbH**, a privately held manufacturer of electronic test and measurement equipment headquartered in Reinach, Switzerland, for $93 M.

ITT Corp. of White Plains, NY, completed the previously announced spin-offs of its Defense and Information Solutions business and its Water Technology and Services business. With the spin-offs complete, ITT is now a $2 B company with four businesses that deliver highly engineered and customized products and services to the industrial, aerospace, transportation, and oil and gas industries.

AWR Corp. and **Magus (Pty) Ltd.**, developers of the Antenna Magus expert system for antenna synthesis, announced a joint marketing relationship focused on accelerating the pace of antenna design for wireless-enabled products. The first result of this relationship is AWR Connected™ for Antenna Magus, an interface between the respective firms' software products that expedites antenna design from synthesis with Antenna Magus to full circuit/EM simulation with AWR's Microwave Office™ and AXIEM® software tools. Antenna Magus provides a database of many different highly characterized antenna types that can be exported to AWR's EDA tools for EM analysis, integration, tuning and optimization.

AMCAD Engineering and **Maury Microwave**, working together under the exclusive development and distribution agreement they signed in June of 2010, announced in October of this year, the release of a new pulser (probe head) tailored for small-periphery transistor (HBTs and HEMT) pulsed IV measurements. This new pulser, AM223, has two embedded measurement units: one for currents lower than 20 mA, one for currents between 20 and 200 mA. This and other features of the new pulser allow for the most accurate characterization of HBTs to date. This new pulser is one of many products being jointly developed by Maury and AMCAD, following their successful launch in 2010 of Maury's IVCAD advanced device characterization software suite, which was the first collaboration between Maury and AMCAD.

TBM Consulting Group, the global business improvement leader for the manufacturing and service sectors, presented the Tukwila plant of **Carlisle Interconnect Technologies** (CarlisleIT) with the 2011 "Perfect Engine" Site Award recognizing the organization for its commitment to a continuous improvement philosophy and its success using operational excellence to drive value creation. The Tukwila plant has also been chosen as one of 16 finalists in IndustryWeek's 2011 Best Plants Competition.

DITF Interconnect Technologies of Minden, NV, was one of 39 companies presented with a supplier excellence award from **Raytheon Co.** in September. The awards are for exceptional performance in supporting the company's Space and Airborne Systems (SAS) business during 2011. They were chosen for meeting demanding standards in the areas of quality and delivery performance, customer satisfaction, and total business and financial health. Awards were presented at the 3- and 4-Star level, and DITF received a 3-Star award.

Special Hermetic Products Inc. (SHP) announced certification to ISO 9001:2008. In business since 1988, SHP is a leader in the design and manufacture of hermetically sealed feedthrus, connectors, headers, assemblies, custom design solutions and related products and services for military, aerospace and commercial applications.

CONTRACTS

KOR Electronics announced that it has been awarded international contracts for simulator products valued in excess of $13.4 M. They include new development contracts for advanced AESA Radar, missile, and Electronic Countermeasure (ECM) simulator systems. These simulators are equipped with the latest KOR Electronics 10/12 Bit 1 GHz Digital Radio Frequency Memories (DRFM).

Crane Aerospace & Electronics Power Solutions was selected by Gulfstream Aerospace Corp. to supply its Transformer Rectifier Units (TRU) on the Gulfstream G650. The five 250A TRUs on each G650 provide DC bus power throughout the aircraft.

PERSONNEL

RF Micro Devices Inc. announced the appointment of technology veteran **Hans Schwarz**, 54, as Corporate Vice President, business development. In this newly created position, Schwarz will be responsible for corporate business development initiatives, including strategic planning, M&A strategy and execution, and IP-based acquisition and licensing for RFMD®. Schwarz will be based in RFMD's West Coast office, in CA's Silicon Valley.

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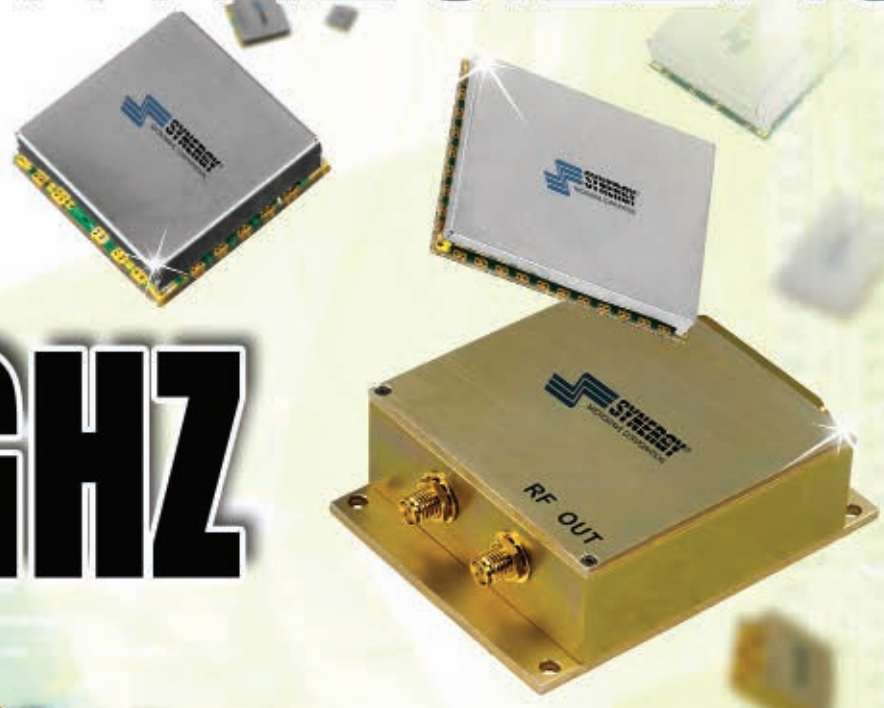

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AROUND THE CIRCUIT

AR RF/Microwave Instrumentation has announced the appointment of **Carl Mueller** to the position of Applications Engineer for the company's EMI Receiver, Conducted Immunity Systems, and test software. Mueller will provide customer support and will also be involved in system development. Mueller has worked as Principal System Engineer on radar warning receivers, communication jamming systems, and aircraft simulated training systems.

REP APPOINTMENTS

Giga-tronics Inc. announced the appointment of **GiGaProM**, as a new sales representative for Russia and the Russian Federation, to cover its growing business in RF and microwave test and measurement equipment. GiGaProM (www.gigaprom.ru) represents a number of leading test and measurement companies in Russia. GiGaProM can be contacted at 7-495-661-67-07 or info@gigaprom.ru.

Pulse Electronics Corp., a leading provider of electronic components, has selected **Microtarget Tecnologia Digital Ltd.** to provide sales, engineering, design support, parts, training, and service for its customers in Brazil and South America. Microtarget will represent Pulse Electronics' antennas, connectors, Excelsus filters, and electronic components for the telecom, LAN, power, RF and wireless, and automotive industries.

Reactel Inc., a manufacturer of RF and microwave filters, multiplexers, and multifunction assemblies to the commercial, military, and industrial markets, announced the appointment of **Eastern Instrumentation / EI Technology** as the company's representative in MD, VA, Washington, DC, eastern PA and southern NJ. For more information about Eastern Instrumentation / EI Technology, visit www.eicorp.com or call (410) 884-7303.

Vaunix Technology Corp., a manufacturer of USB controlled and powered test equipment, hired two new sales representatives, **Sea-Port Technical Sales** and **Clarke and Severn Electronics**, to handle customer relationships in WA/OR and Australia/New Zealand, respectively. Sea-Port Technical Sales offers a suite of RF, microwave and fiber-optic products: components, modules and subassemblies, design software, and manufacturing/engineering services. Vaunix representative Tom Raschko can be reached by phone at (425) 702-8300 or by email at Tom@seaporttech.com. Clarke and Severn Electronics is a distributor of electronic components and products. Vaunix representative David Haimovich can be reached by phone at +61-2-94821944 or by email at davidh@clarke.com.au.

W.L. Gore & Associates Inc. announced that **Astron Electronics Inc.**, Gore's authorized sales representative in southern CA, will now sell Gore's high performance line of test and measurement RF/microwave cable assemblies, including GORE® PHASEFLEX®. To view Gore products on Astron's website, visit www.astron1.com or call (949) 379-7266.

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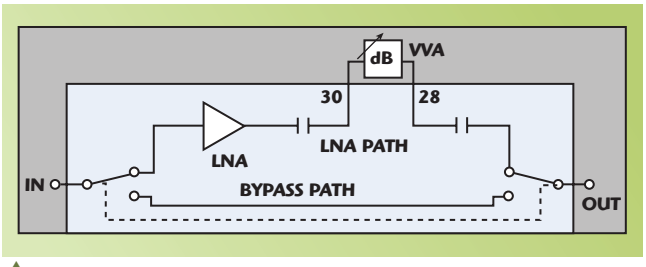
WIDEBAND VOLTAGE VARIABLE ATTENUATOR WITH FEWER COMPONENTS

The cellular infrastructure equipment is subject to intense pricing and size pressures. Recently, a Rubik's Cube size base station has been demonstrated.[1] Both cost and size can benefit from reducing the number of circuit elements in a function block. Low noise amplifiers (LNA), fabricated using contemporary semiconductor technologies, have some degree of gain variability. For example, 0.9/1.9/2.5 GHz LNAs, fabricated on 0.25 µm GaAs enhancement mode pseudomorphic (EPHEMT) process, require 3 dB gain specification windows.[2-4] In critical applications, voltage-variable attenuators (VVA) are required for gain leveling. Some contemporary LNAs for base station applications have dedicated ports for connecting to external VVAs (see ***Figure 1***).



▲ *Fig. 1 Block diagram of an LNA module with provision for connecting an external VVA.*

PIN diodes, configured as the PI or the bridged-TEE topologies, are commonly used for realizing wideband, high linearity and compact VVAs. The commercial availability of pre-configured diode arrays,[5,6] and stand-alone modules[7] can minimize the design effort and space requirement. These PIN diode VVAs typically contain 14 to 18 circuit elements each (see ***Table 1***) and these numbers have remained constant for two decades. So, a tantalizing route to size and cost reduction lies in reducing this quantity. Another argument against employing conventional topologies is that they typically have more than 30 dB of dynamic range (DR), whereas gain alignment requires far less.

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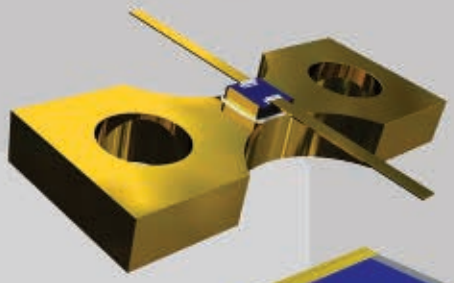
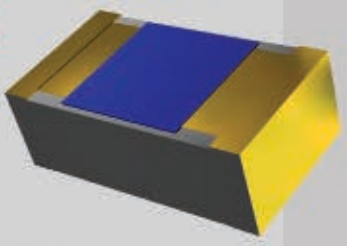
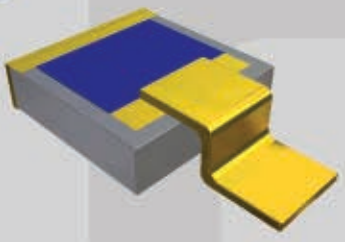
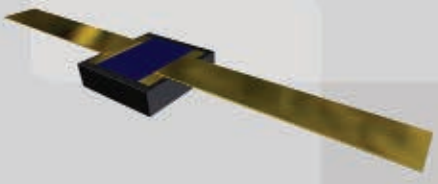


20 Watts in 0402 Package







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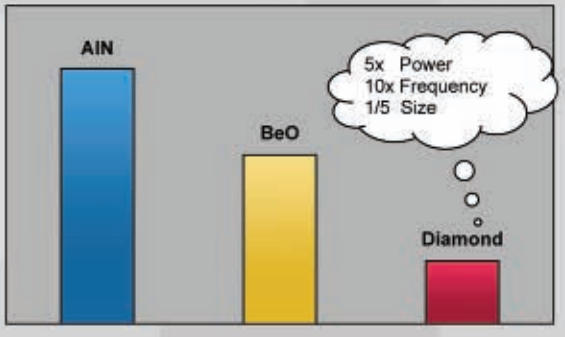
Common Substrate pF / Watt Comparison



Common Substrate RF Performance

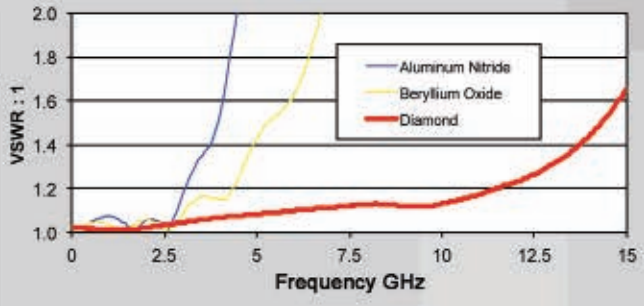


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TABLE I

COMPARISON OF THE NUMBER OF CIRCUIT ELEMENTS IN VARIOUS COMPACT, WIDEBAND VVAs

Topology	No. Circuit Elements		
	Active	Passive	Total
3-diode PI [8, 9]	4	14	18
Waugh 4-diode PI [10, 11]	4	10	14
Bridged TEE [12]	2	12	14
This Work	1	4	5

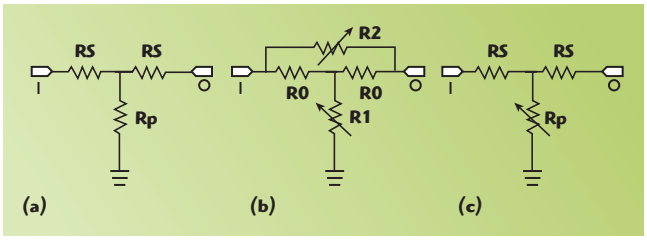

Fig. 2 Fixed TEE (a), bridged TEE (b) and one variable resistance TEE (c) attenuators.

the TEE topology that utilizes only one variable element has been explored. Although it has a significantly reduced DR, it is, nevertheless, sufficient for gain alignment. This article describes the design and construction of the variable resistance circuit, as well as its modeling and performance.

TEE VVA TOPOLOGY

The new VVA configuration evolved from the fixed TEE attenuator (see ***Figure 2***). For a specific characteristic impedance (Z_0) and attenuation (A), TEE attenuator's series (Rs) and shunt (Rp) resistors are given by:[13]

$$Rp = \left(2\sqrt{(Z_0^2 . 10^{A/10})}\right) / \left(10^{A/10} - 1\right) \quad (1)$$

$$Rs = \left(\left(\left(10^{A/10} + 1\right) / \left(10^{A/10} - 1\right)\right) Z_0\right) - Rp \quad (2)$$

VVAs rarely are based on the TEE topology because all three resistors must be varied simultaneously to keep Z_0 constant. Instead, a variation known as the bridged-TEE is more popular because only two resistances need to be varied.[14] A proposed modification to the TEE topology, whereby only Rp is varied, works on the premise that Z_0 deviates minimally for small excursion in the value of Rp. As a larger change in Rp will skew Z_0 from the system reference impedance, the dynamic range is limited by the worst return loss that can be tolerated. When the required dynamic range is relatively small, the proposed configuration can advantageously replace conventional topologies for component reduction. Although the narrowband attenuators, like the hybrid coupled and the resistive line, can also achieve low component count, they are either expensive or require a large PCB area. The variable resistance can be chosen from either field-effect transistor (FET) or PIN diode and the entire VVA can be fabricated in monolithic or discrete forms. It is possible that this configuration is not new because it is so simple, but a literature search did not unearth any similar work. The value of Rs determines the compromise between minimum attenuation and dynamic range (see ***Figure 3***). As previously discussed, the dynamic range is limited by the increasing impedance mismatch for larger deviation of Rp and so, a return loss limit of 10 dB was used as the constraining parameter in the simulation. The simulation also assumes ideal components.

VARIABLE RESISTANCE ELEMENT

Although either a FET or PIN diode can function as the variable resistances, the optimal technology will depend on the application. For example, the former's microAmp-level operating current[15] will be clearly advantageous in battery-powered equipment. Whereas in mains-powered equipment, such as cellular base stations, the latter's high linearity[16] will be more useful than power saving. A

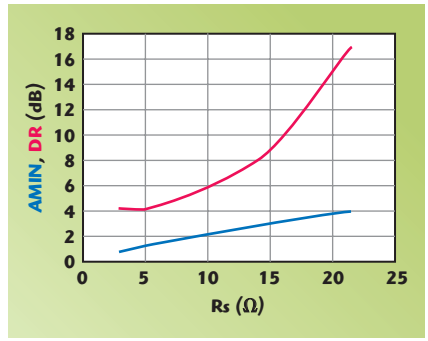

Fig. 3 Dynamic range and minimum attenuation vs. Rs.

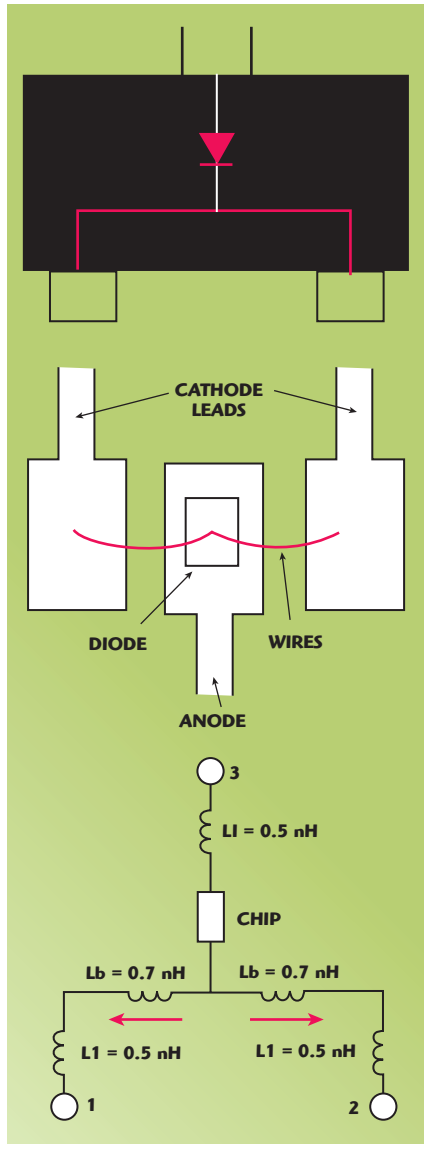

Fig. 4 Simplified circuit of the HSMP-481 dual cathode PIN diode.

PIN diode with the following salient characteristics – 125 µm I-layer thickness and 1500 nS carrier lifetime[17] – was selected to realize the VVA, because it has the highest linearity in the diode portfolio.

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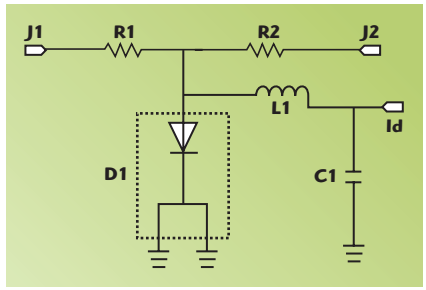

Fig. 5 Circuit diagram of a 1-diode TEE VVA.

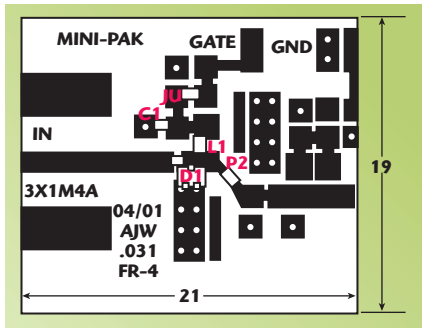

Fig. 6 PCB used for experimental verification of the 1-diode TEE VVA.

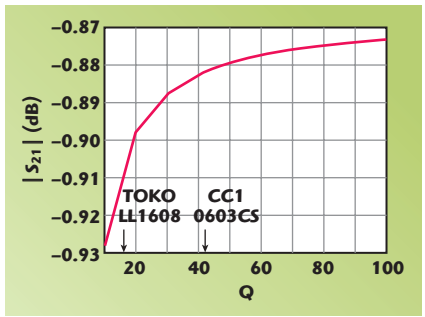

Fig. 7 Simulated minimum attenuation at 1.85 GHz vs. L1's unloaded Q.

age style, as shown in ***Figure 4***, was chosen because of its better high frequency performance than a conventional single-cathode package. Ordinarily, the parallel cathode paths results in half the inductance and, by inspection of the package model, the sum of the parasitic inductances is Ll + ((Lb + Ll)/2). Using the manufacturer-supplied model parameters,[18] the total package inductance adds up to approximately 1.1 nH. However, when the two bond-wires are arranged such that their currents flow in the opposite directions, the resultant mutual inductance, M, lowers the effective bond-wire inductance to (Lb – M)/2.[19] So, the actual total inductance could be considerably lower than the simple calculation, which did not account for mutual inductance.

For linear structures, such as two straight wires separated by "d" and of a height "h" above ground, M can be determined analytically from:

$$M \approx 0.1 \ln\left[1 + \left(2h / d\right)^2\right] \qquad (3)$$

Unfortunately, M cannot be easily determined for bond-wires because the height changes along their length (usually referred to as "loop profile"). Since it is necessary to account for the bond-wires equivalent inductance in the simulation, a value of 0.35 was assumed for M; the value was chosen without any expectation of accuracy.

ASSEMBLY AND MODELING

To achieve the target DR of approximately 4 dB, an Rs value of 5.1 Ω was selected for the evaluated circuit (see ***Figure 5***). The 0.8 mm thick FR-4 PCB was designed for a different project and so has many unused pads (see ***Figure 6***). The microstrip traces associated with the VVA input and output connections are dimensioned for a 50 Ω characteristic impedance. The value of L1, which chokes the DC bias, was chosen to suit the 2 GHz upper frequency limit. A multilayer inductor was chosen to save cost because preliminary simulation with a higher Q inductor (such as wirewound) showed insignificant improvement (~0.03 dB) in circuit loss. ***Figure 7*** shows the simulated minimum attenuation versus L1's unloaded Q, excluding the PCB and connector losses. The arrows mark the published typical Q at 1.8 GHz for Toko LL1608 wirewound inductor and Coilcraft 0603CS multilayer inductor. ***Table 2*** is the part list of the 1-diode TEE VVA.

The VVA was modeled so that its

TABLE II
TEE VVA PART LIST

Pos.	Value	Remark
C1	1 nF	0603
D1	HSMP-481B	
J1, J2	142-0701-881	Johnson
JU	0R	0603
L1	33 nH	Toko LL1005
R1, R2	5R1	0603

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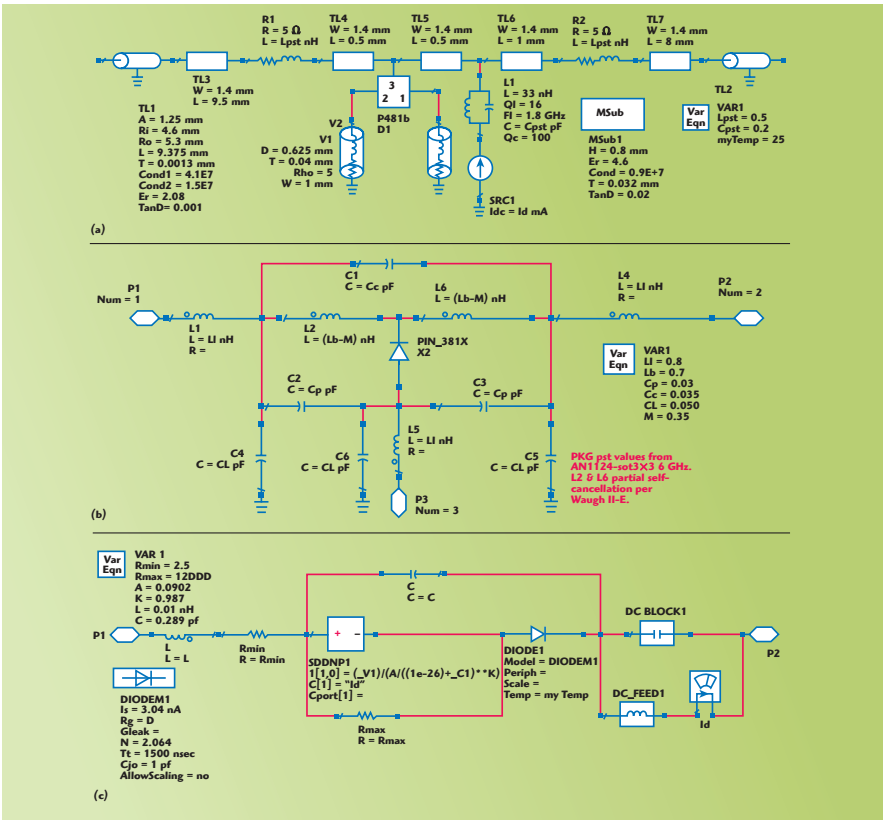
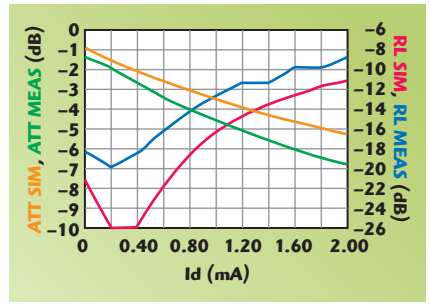


▲ *Fig. 8 Nested models of (a) complete VVA, (b) packaged diode and (c) diode current-controlled resistance.*



▲ *Fig. 9 Simulated and measured attenuation and return loss vs. diode current at 870 MHz.*

performances could be evaluated in a linear simulator. The models nest in a 3-level hierarchy shown in ***Figure 8***: the complete PCB assembly at the top (a), the packaged diode in the middle (b) and the diode equivalent resistance at the bottom (c). The RLC equivalent circuits comprise only the first-order parasitic and are created after the Rhea intuitive method of whittling away lesser parasitic.[21] Specifically, the resistors' predominant parasitic (Lpst) was decided using a rule[22] and the value was guesstimated. The inductor L1 parasitic capacitance Cpst was calculated from the self resonance frequency specified by the manufacturer. The diode package model follows the SOT-323 model published by the manufacturer,[23] but additionally accounts for lower bond-wire inductance, due to mutual inductance. The current dependent resistance follows the APLAC linear representation of the HSMP-381x PIN diode.[24]

RESULTS AND DISCUSSION

The experimental results at the nominal cellular frequencies of 870 MHz and 1.85 GHz are > 4.5 dB dynamic range, –1.5 dB minimum attenuation and +53.5 dBm third order intercept point (OIP3). The simulation and measurements agree reasonably. The measured attenuation changes from –1.5 dB to –6 dB at 870 MHz when the current is swept over a 0 to 1.6 mA range – the current is constrained to this range to ensure better than a 10 dB return loss (see ***Figure 9***). A comparable PI VVA needs 0 to +10 mA operating current range and has a minimum attenuation of –4 dB.[25] When cascaded with an LNA, the improved minimum attenuation limit (e.g. –1.5 dB vs. –4 dB) is less degrading to the

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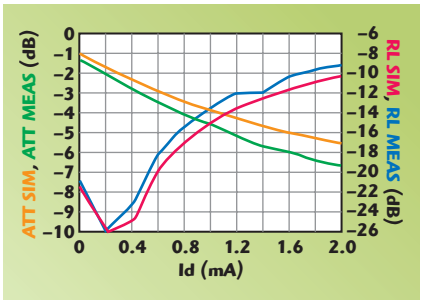

Fig. 10 Simulated and measured attenuation and return loss vs. diode current at 1.85 GHz.

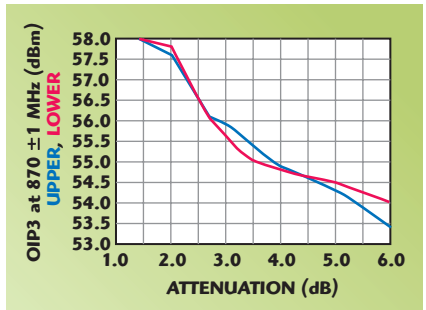

Fig. 11 Output third-order intercept point vs. attenuation at 870 ±1 MHz.

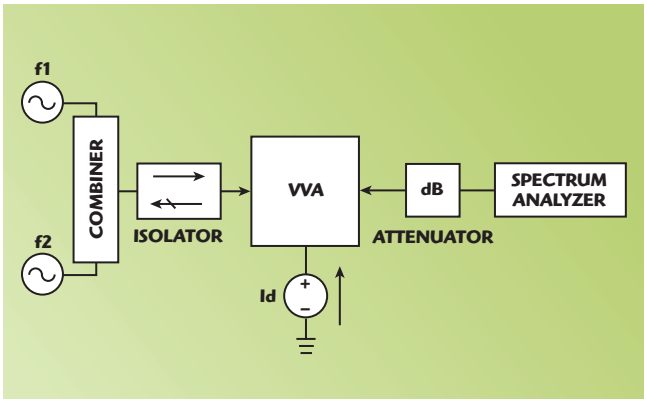

Fig. 12 Simplified diagram of the IP3 measurement setup.

noise figure. Maximum simulation errors are 1.7 and 8 dB for attenuation and return loss, respectively. Inaccurate PIN diode APLAC parameter values and component models are the suspected causes of the simulation errors. The attenuation can be varied from –1.4 to –6 dB at 1.85 GHz; this also assumes that the current is limited to 0 to 1.6 mA to ensure better than a 10 dB return loss (see ***Figure 10***). The maximum simulation errors are 1.2 and 2 dB for attenuation and return loss, respectively.

The OIP3 is as high as for the PI topology's. Using 869 and 871 MHz input signals at 25 dBm, the OIP3 decreases in an almost 1-to-1 manner with increasing attenuation but remains above 53.5 dBm (see ***Figure 11***). The OIP3 at 1.85 GHz was not measured, but is expected to be higher, because it has been previously reported that a silicon PIN diode's OIP3 increases linearly with frequency.[26] The distortion is caused by RF currents modulating the I-layer's charge density. So, the distortion increases with attenuation because a larger fraction of the RF currents is diverted from the load to the diode.

CONCLUSION

The 1-diode TEE VVA contains only one-third of the total components in the equivalent PI and bridge-TEE topologies, but can fulfill the same gain-leveling role. Additionally, it is capable of lower attenuation than a PI VVA built with similar diodes, has comparable linearity and yet operates at the fraction of the current. The much-improved minimum loss limit will benefit the cascaded noise figure. A simple design chart has been provided for designing to different dynamic range and minimum attenuation targets.

Beside the PIN diode, the FET is equally suited as the variable element. In fact, implementation in monolithic FET technology should result in the lowest cost and size. While the design is presented in the context of cellular LNA gain alignment, it should find use in other applications that do not require the conventional VVA's large dynamic range, such as automatic level control in power amplifiers and signal generators. It is anticipated that the proposed configuration will lead to improvement in the base station LNA's size, cost, power consumption and sensitivity. ■

ACKNOWLEDGMENTS

The author thanks his mentor, R.W. Waugh, who originated the 1-diode TEE VVA idea, S.A. Asrul for reviewing the paper and the management of Avago Technologies for approving the publication of this work.

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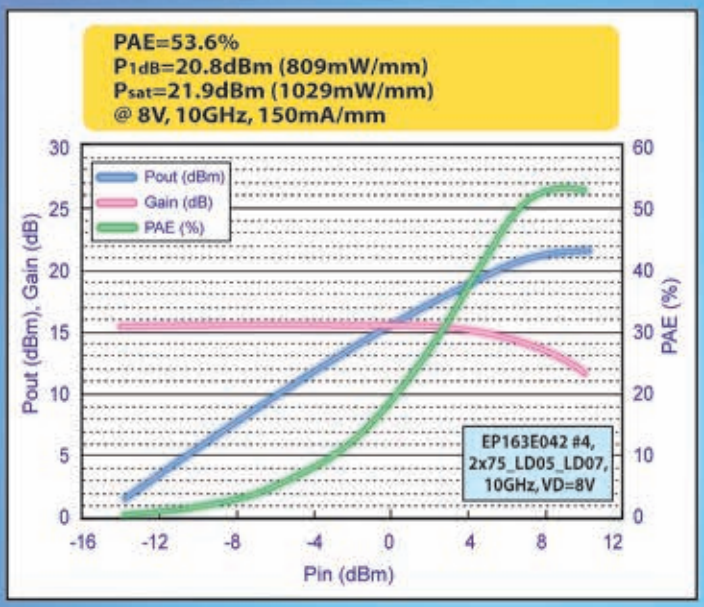

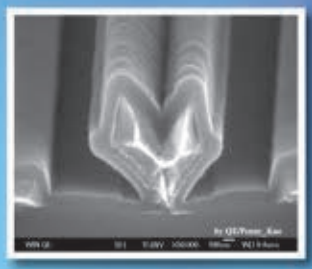

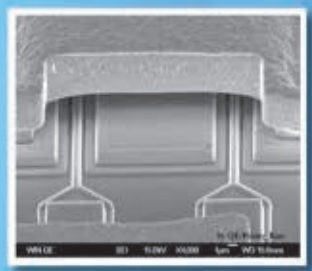

Comparison Table for 0.1µm, 0.15µm, 0.25µm and 0.5µm pHEMT

	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
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APPENDIX: THIRD ORDER DISTORTION MEASUREMENT

High IP3 is generally difficult to measure due to the great difference between fundamental and intermodulation amplitudes. Depending on the attenuator's setting (see ***Figure 12***), the intermodulation products could either be overshadowed by the spectrum analyzer's internally generated distortion or have insufficient margin from the noise floor. Additionally, cross modulation between the signal sources can create artifacts that are indistinguishable from the real distortion. A tutorial[27] lists the necessary hardware and procedures for enhancing measurement accuracy. To ensure that the setup used for the VVA evaluation did not contribute to the intermodulation results, its IP3 was measured at 62.8 dBm (versus the VVA's best case OIP3 of 58 dBm).

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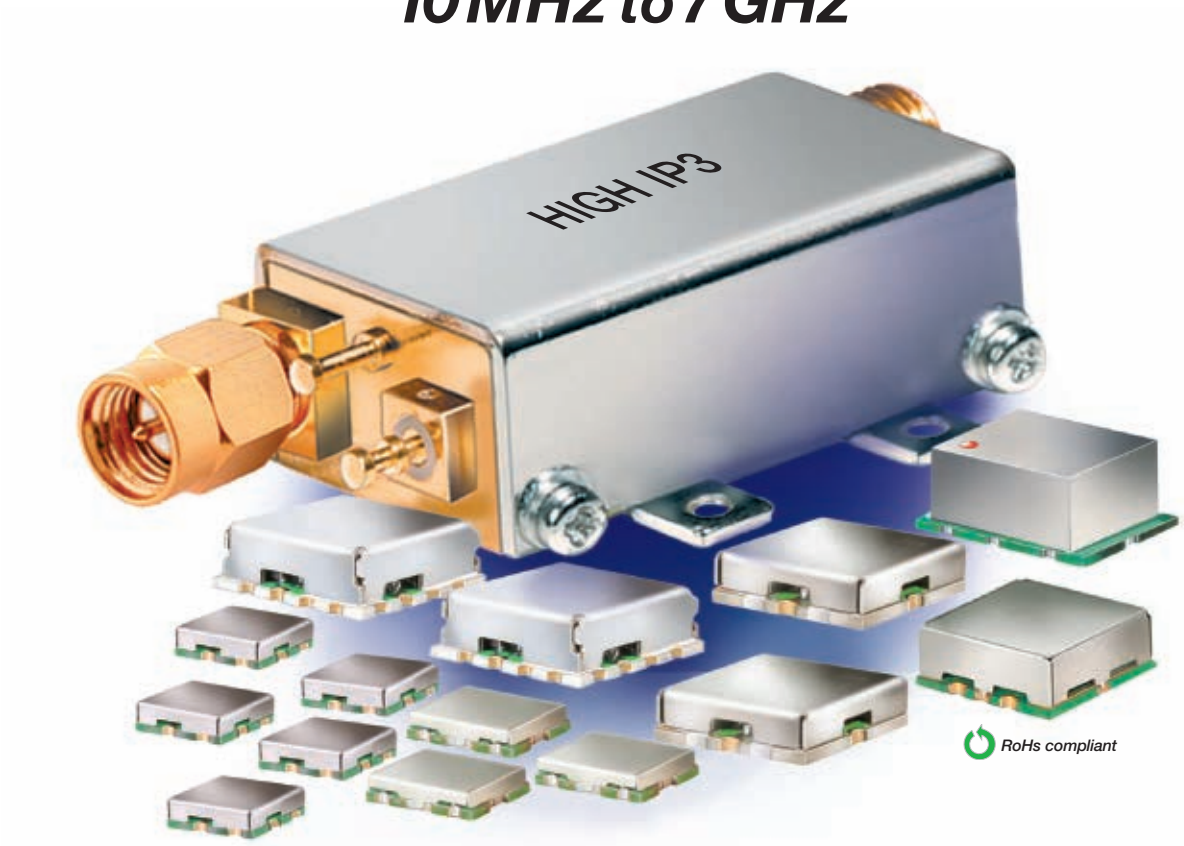

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Due to the explosive growth of various wireless communication services, today's microwave communication systems often require multi-band operations. For example, global systems for mobile communications (GSM) operate at both 900 and 1800 MHz, IEEE 802.11a and IEEE 802.11b wireless local area networks (WLAN) products operate in the unlicensed industrial, scientific and medical (ISM) 2.4 and 5 GHz bands, respectively. The compactness, low insertion loss in passbands and wide stopbands are three main standards for judging the performance of a filter, and in order to achieve these goals, various methods have been proposed.[1-16] Dual-band BPFs have been designed by combining two separated filters with two specific single passbands or cascading a wideband BPF and a stopband filter, but they suffer from excess sizes and high insertion losses.[1,2] Stepped-impedance resonators (SIR) have been employed in dual-band BPFs design. However, the resonant frequencies of SIRs are dependent in some cases, which makes the filter design complicated.[4,5]

On the other hand, microstrip filters with dual-mode response are also attractive, because each dual-mode resonator can be used as a doubly tuned resonant circuit. Thus, the number of resonators required for a given degree of filter is reduced by a half, resulting in a compact filter configuration. Therefore, dual-mode, dual-band filters have received much attention.[8-16] Dual-mode, stub-loaded resonators (SLR) have been successfully used to design dual-band BPF with good performance for their characteristic of easy control of resonant frequencies.[8-10] The SLR has some very important properties. First, there are two main

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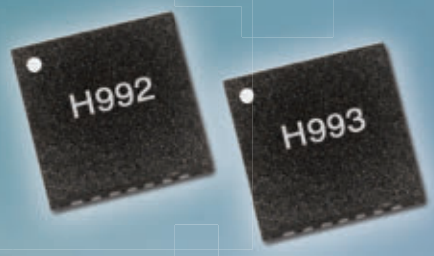

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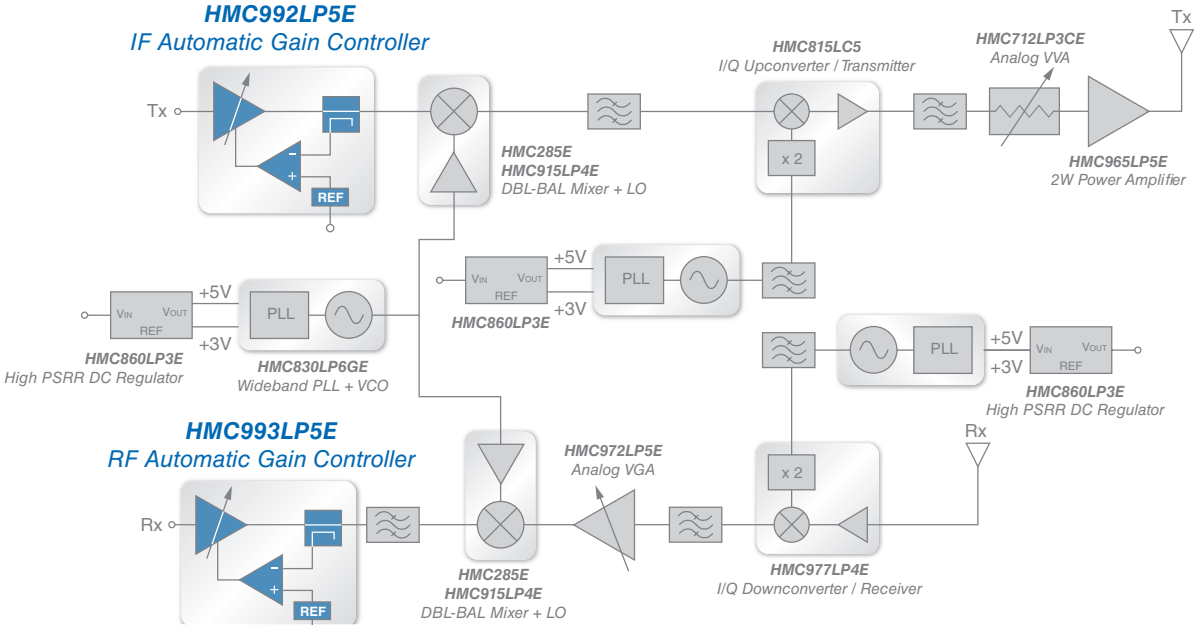

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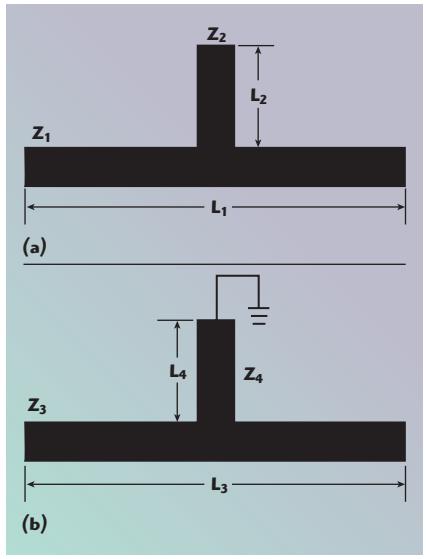

▲ *Fig. 1 Schematics of the OSLR (a) and SSLR (b).*

coupling paths between source and load. Second, for the dual-mode resonators, the two modes are not coupled to each other. Thus, the dual-mode filters are special, two-order, full canonical transversal filters. The two-order full canonical transversal filter has an inherent transmission zero in the stopband.[17] By introducing source-load coupling (S-L coupling), additional transmission zeros are created near the passband.[18] Furthermore, due to the intrinsic characteristics of a transversal filter, the bandwidths of the two bands can be adjusted over a relatively wide range.

In this article, a dual-mode, dual-band, microstrip filter incorporating an SSLR and an OSLR is proposed. Additional transmission zeros are obtained by the widely used ways of introducing S-L coupling. Consequently, a 2.4/5 GHz dual-band bandpass filter is designed with multiple transmission zeros on either side of both passbands.

CHARACTERISTICS OF STUB-LOADED RESONATORS

Figure 1 shows the schematic models of the OSLR and SSLR, either of which comprises a half-wavelength resonator and an open stub or a short stub shunted at the midpoint. Z_1, L_1, Z_2, L_2, Z_3, L_3, Z_4 and L_4 are the characteristic impedances and lengths of the half-wavelength resonator and open or short stub in each SLR. The two SLRs are symmetrical in structure. Thus, odd- and even-mode analysis can be adopted.

For the odd-mode resonance of the OSLR, the symmetry plane behaves as an electric wall, along which there is a voltage null. Thus, the plane is short circuited. The resonant condition is

$$\theta_1 = \pi \quad (\text{at } f = f_{oO}) \tag{1}$$

where $\theta_1 = \beta L_1$ is the electric length of the half-wavelength resonator in the OSLR, and f_{oO} is the odd-mode resonant frequency of the OSLR, given as:

$$f_{oO} = \frac{c}{2L_1\sqrt{\varepsilon_{eff}}} \tag{2}$$

where c is the speed of light in free space, and ε_{eff} denotes the effective dielectric constant of the substrate.

For the even-mode resonance of the OSLR, the symmetry plane, on the contrary, behaves as a magnetic wall, through which no current flows. The resonant condition in this case will be

$$\cot(\theta_1/2)\tan(\theta_2) = -\frac{2Z_2}{Z_1}$$

$$(\text{at } f = f_{eO}) \tag{3}$$

where $\theta_2 = \beta L1$ is the electric length of the open stub, and f_{eO} is the even-mode resonant frequency of the OSLR. For the special case $Z_1 = 2Z_2$, it can be deduced that

$$f_{eO} = \frac{c}{(L_1 + 2L_2)\sqrt{\varepsilon_{eff}}} \tag{4}$$

As for the SSLR, the first resonant frequency is an even-mode. The resonant condition is given by

$$\tan(\theta_4)\tan(\theta_3/2) = \frac{Z_3}{2Z_4}$$

$$(\text{at } f = f_{eS}) \tag{5}$$

where θ_3 and θ_4 are the electric length of the half-wavelength resonator in the SSLR and the short stub, respectively. f_{eS} is the even-mode resonant frequency of the SSLR. For the special case of $Z_3 = 2Z_4$, the resonant frequency here can be derived as

$$f_{eS} = \frac{c}{2(L_3 + 2L_4)\sqrt{\varepsilon_{eff}}} \tag{6}$$

For the odd mode in the SSLR, the resonant characteristic is almost the same as that of the OSLR, which is mainly determined by the half-wave-

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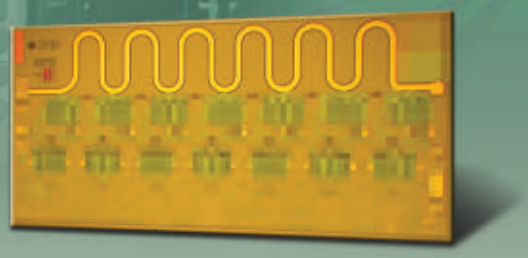

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	22 - 26.5	Power Amplifier, 1/2 Watt	21.5	33	26.5	+6V @ 350mA	LP4	HMC863LP4E
	27.3 - 33.5	Power Amplifier, 2 Watt	23	43	33	+6V @ 1200mA	Chip	HMC906
	37 - 40	Power Amplifier, 1 Watt	21	38	30.5	+6V @ 900mA	Chip	HMC968
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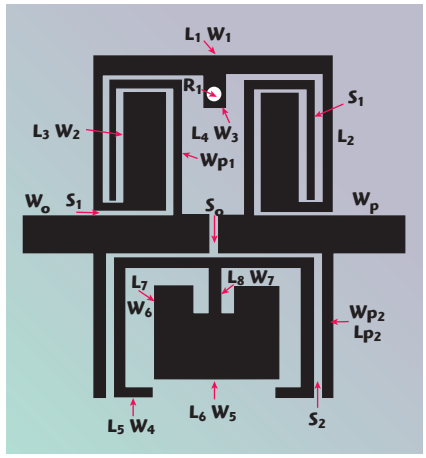

Fig. 2 Layout of the proposed dual-mode, dual-band filter.

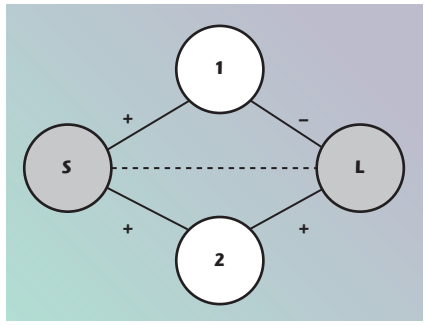

Fig. 3 Layout of the corresponding coupling scheme of each band.

length resonator. Therefore, the odd mode resonant frequency of the SSLR can be given by

$$f_{oS} = \frac{c}{2L_3\sqrt{\varepsilon_{eff}}} \quad (7)$$

Therefore, by properly choosing the value of L_3 and L_4, using Equations 6 and 7, the even- and odd-modes of the SSLR together, can generate the first passband of the filter. By properly choosing the value of L_1 and L_2 using Equations 2 and 4, the even- and odd-modes of the OSLR together, can generate the second passband of the filter.

DESIGN OF THE DUAL-MODE, DUAL-BAND BPF WITH MULTIPLE TRANSMISSION ZEROS

The configuration of the proposed dual-mode, dual-band filter is shown in ***Figure 2***. The SLRs used here are SSLR and OSLR with source-load coupling. The SSLR is operated at an even and odd resonance in the first passband and the OSLR is operated in the second band. Namely, the resonant frequencies in the first band are f_{eS} and f_{oS}, and f_{oO} and f_{eO} in the second band. The signal is coupled to the OSLR and the SSLR at the same time, while no coupling between resonators is introduced, providing two main paths to load for each passband signal.

The corresponding coupling scheme for each band is shown in ***Figure 3***, where 1 and 2 represent the odd and even modes, respectively. The signal is coupled to each resonator at the same time, providing two main paths for the signal between the source and load, and no coupling between each mode is introduced. Therefore, the two-order full canonical transversal filter theory can explain the dual-mode resonator.[17,18] In each band, a different resonator operates at an even and odd mode, respectively. The coupling matrix can be written as

$$\begin{pmatrix} 0 & M_{S1} & M_{S2} & M_{SL} \\ M_{S1} & M_{11} & 0 & M_{1L} \\ M_{S2} & 0 & M_{22} & M_{2L} \\ M_{SL} & M_{1L} & M_{2L} & 0 \end{pmatrix} \quad (8)$$

The dual-mode resonator exhibits symmetry, so the relationship $M_{S1} = -M_{1L}$ and $M_{S2} = M_{2L}$ holds. An inherent transmission zero can be created near each band due to two main path signals counteraction, as explained by Cameron,[18] which can be provided in a lowpass prototype as follows:

$$\Omega_{inh} = \frac{M_{11}M_{S2}^2 - M_{22}M_{S1}^2}{M_{S1}^2 - M_{S2}^2} \quad (9)$$

Thus, the inherent transmission zero can be shifted from one side of the passband to the other side by properly choosing the relative values of M_{S1} and M_{S2} as well as the signs of M_{11} and M_{22}. The additional transmission zeros can be created by introducing capacitive S-L coupling. Therefore, multiple transmission zeros can be achieved on both sides of the passband, which can improve the selectivity of the passband and reject unwanted signals above the passband. The design process is simple, because there is no coupling between each mode. Each band can be designed, respectively, by the coupling matrix without changing the other band response.

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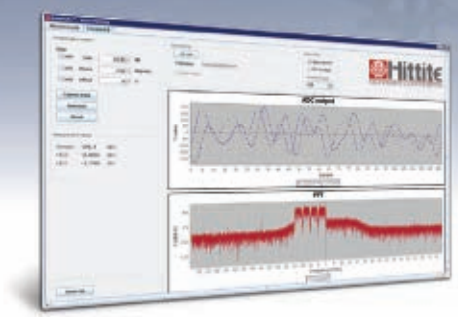

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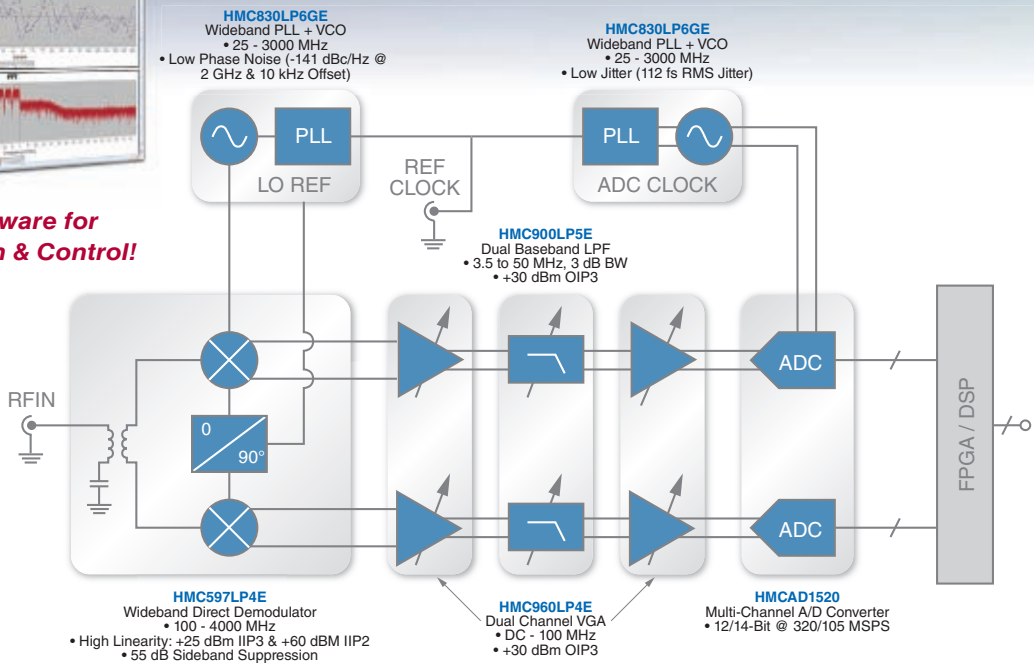

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dual-band filter is designed to validate the concept. The coupling matrix is shown in Equation 8. The substrate used here is Duroid 5880 with a thickness of 0.508 mm. The final structure parameters of the bandpass filter are as follows: W_o = 1.52 mm, W_1 = 0.3 mm, W_2 = 1.95 mm, W_3 = 1 mm, W_4 = 0.4 mm, W_5 = 2.8 mm, W_6 = 1.3 mm, W_7 = 0.6 mm, Wp = 1.6 mm, Wp_1 = 0.3 mm, Wp_2 = 0.3 mm, R_1 = 0.3 mm, L_1 = 9.4 mm, L_2 = 6.2 mm, L_3 = 5 mm, L_4 = 1.4 mm, L_5 = 1.6 mm, L_6 = 5.6 mm, L_7 = 1.9 mm, L_8 = 2 mm, S_o = 0.3 mm, S_1 = 0.2 mm, S_2 = 0.2 mm. The total area of the proposed filter is 9.4 × 14.2 mm, which corresponds to a size of 0.1 λ × 0.15 λ, where λ is the guided wavelength at the center frequency 2.4 GHz. Thus, the proposed filter is very compact. ***Figure 4*** shows the photograph of the fabricated filter.

SIMULATION AND MEASUREMENT RESULTS

Figure 5 shows the simulated and measured results, which are in good agreement. There are two transmission poles inside each passband, which correspond to the two resonance modes of the dual-mode resonators. The measured minimum insertion losses for the two passbands are 1.5 and 1.7 dB, respectively. There exists multiple transmission zeros with better than 45 dB suppression on the outsides of each passband, as expected. The measured 3 dB absolute bandwidths for the lower and upper passbands are 200 and 90 MHz, respectively. Furthermore, the spurious frequencies are suppressed from 5.1 GHz up to 8.7 GHz, with better than 20 dB suppression. There is a slight response discrepancy at 5 GHz between the simulated and measured results. This phenomenon is due to the resonant frequency shift of the resonators, which might be due to a variation of the material characteristic at higher frequencies and manufacturing effect. It can be rectified by slightly adjusting the dimensions of the open stub loaded dual-mode resonator. Thus, the proposed filter is characterized with low insertion loss, compact size and high selectivity.

CONCLUSION

A new dual-mode, dual-band, microstrip bandpass filter has been presented. The filter employs stub loaded dual-mode resonators together with S-L coupling to control the transmission zeros. Multiple transmission zeros are created to improve the performance of the filter by utilizing source-load coupling and two main paths

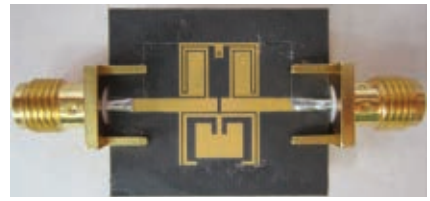

Fig. 4 The photograph of the fabricated dual-mode, dual-band BPF.

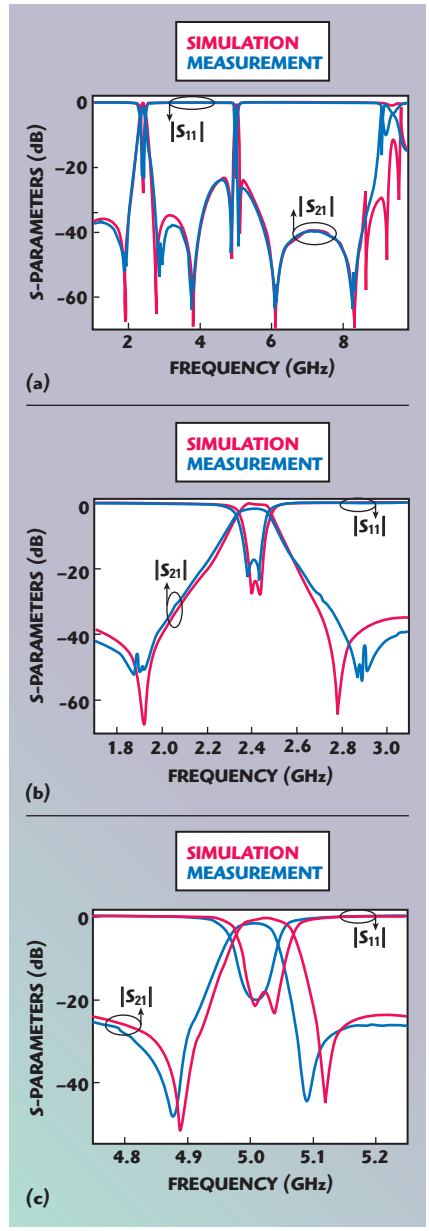

Fig. 5 Measured and simulated frequency responses (a) wideband, (b) narrowband at 2.4 GHz and (c) narrowband at 5 GHz.

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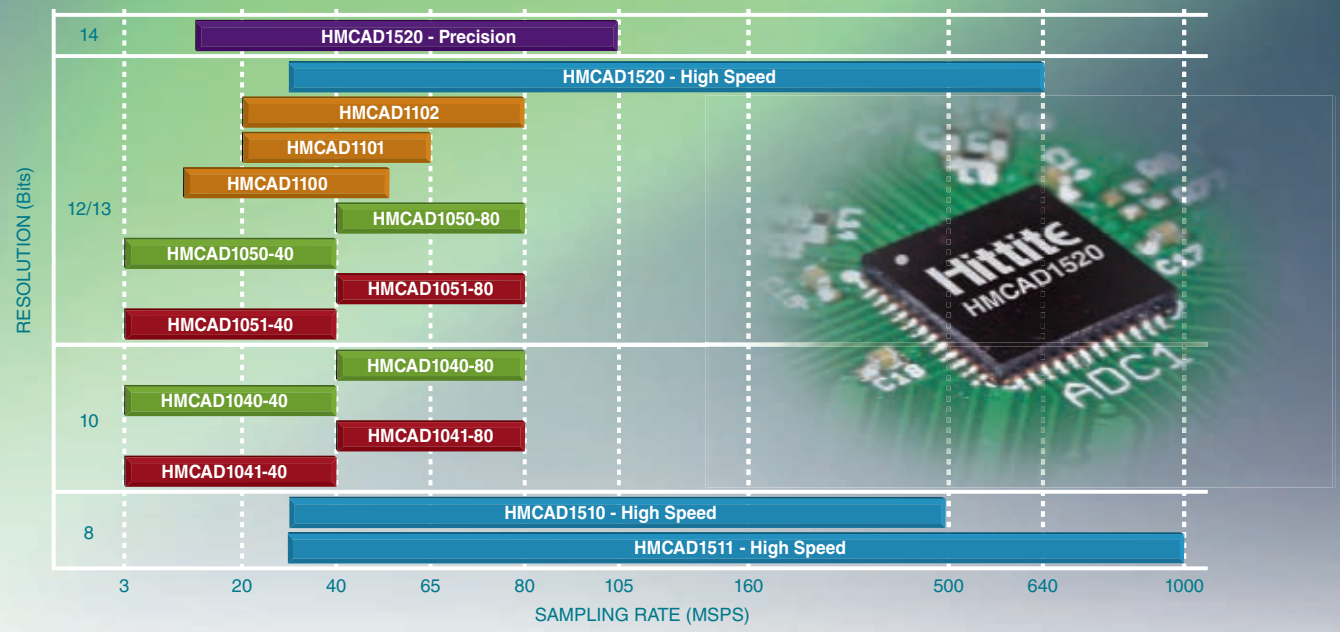

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HMCAD1100	13 / 12-Bit	50 MSPS	8	41 mW / Channel	72.2	82	LP9	EKIT01-HMCAD1100
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HMCAD1050-40	13 / 12-Bit	40 MSPS	2	55 mW	72.7	81	LP9	EKIT01-HMCAD1050
HMCAD1051-80	13 / 12-Bit	80 MSPS	1	60 mW	72	77	LP6H	EKIT01-HMCAD1051
HMCAD1051-40	13 / 12-Bit	40 MSPS	1	33 mW	72.7	81	LP6H	EKIT01-HMCAD1051
HMCAD1040-80	10-Bit	80 MSPS	2	78 mW	61.6	75	LP9	EKIT01-HMCAD1040
HMCAD1040-40	10-Bit	40 MSPS	2	43 mW	61.6	81	LP9	EKIT01-HMCAD1040
HMCAD1041-80	10-Bit	80 MSPS	1	46 mW	61.6	75	LP6H	EKIT01-HMCAD1041
HMCAD1041-40	10-Bit	40 MSPS	1	25 mW	61.6	81	LP6H	EKIT01-HMCAD1041

[1] Excluding Interleaving Spurs. [2] Supply Voltage (Vdd): +1.8 Vdc Analog Supply (AVdd) and +1.8 Vdc Digital Supply (DVdd). [3] Output Supply Voltage (OVdd): +1.7 to +3.6 Vdc.

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signal counteraction. One sample filter with two passbands located at 2.4 and 5 GHz has been designed and measured for demonstration. Results indicate that the proposed filter has the properties of compact size, low passband insertion loss and high selectivity. With all these good features, the proposed filter is applicable to modern wireless communication systems. ■

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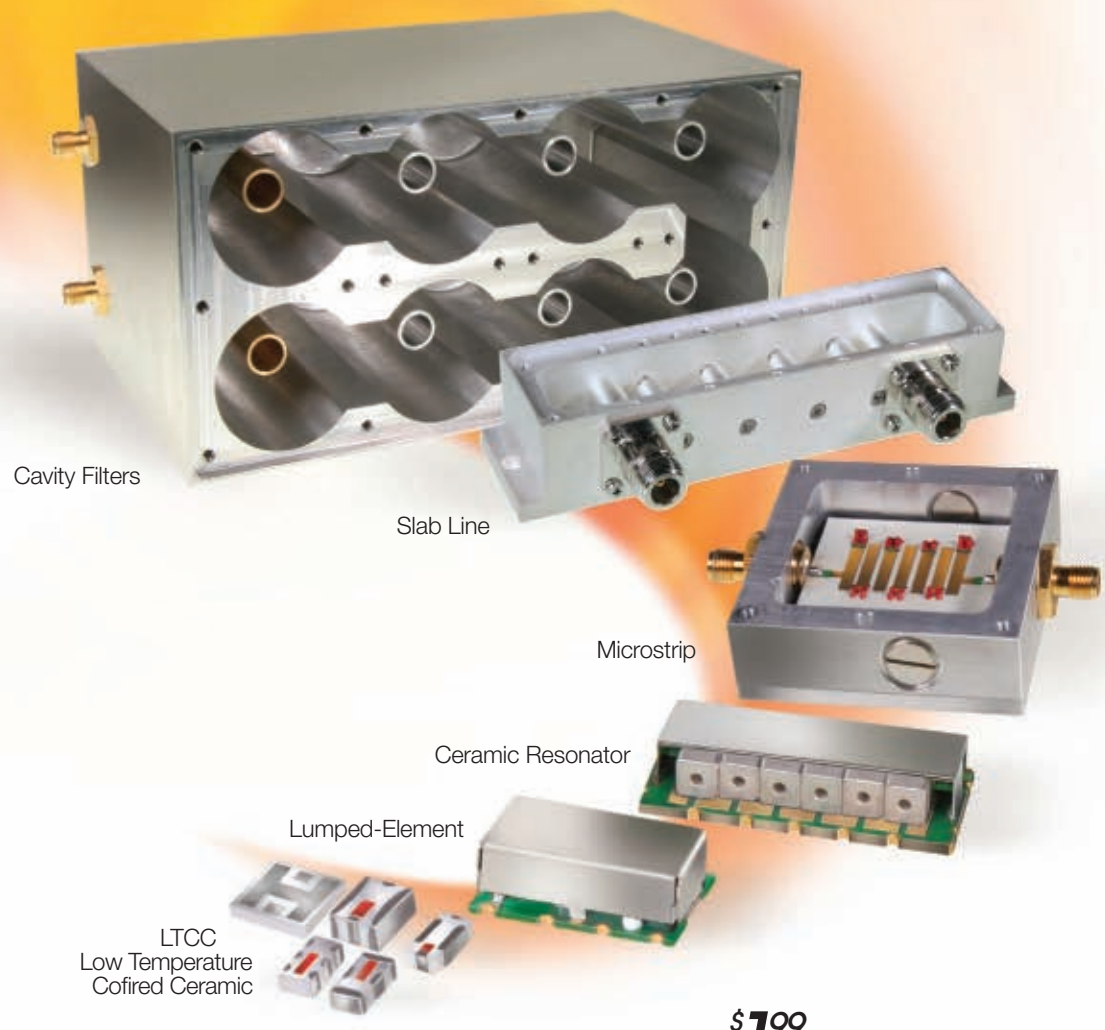

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AUTOMATED CAVITY PERTURBATION METHOD FOR MEASUREMENT OF DIELECTRIC CONSTANT

The cavity perturbation method is a well established technique for the measurement of dielectric properties of materials at microwave frequencies. This article presents an automated cavity perturbation technique at X-Band, using a VNA and LabVIEW software. Being an automated procedure, the method is repeatable and avoids any uncertainties of manual measurements. The computer algorithm for automation of data acquisition and the overall experimental setup is presented.

Cavity perturbation techniques[1,2] have been widely used for the measurement of dielectric properties at microwave frequencies. The fundamental concept of this technique is that the presence of a small volume of dielectric sample in the resonant cavity will not significantly perturb the electromagnetic field around the loaded sample and the shift in resonant frequency of the loaded cavity has been computed with these assumptions. The dielectric constant and loss tangent of the specimen can be calculated from the shifts of resonant frequency and the change in quality factor.[1,2]

LabVIEW[3] is a high level graphical programming language that is designed for data acquisition and control. This article describes an automated procedure based on LabVIEW software to measure the dielectric properties of the material, which are dielectric constant and loss tangent. The measurement setup uses a rectangular waveguide TE_{103} cavity resonator, an HP8510 Network Analyzer and a personal computer.

CAVITY PERTURBATION TECHNIQUE

In the cavity perturbation method, the sample under test is positioned at the maximum electric field in the resonant cavity then the change in resonant frequency and Q of the cavity in loaded and unloaded conditions is measured using a standard resonant rectangular cavity in the TE_{103} mode. The sample under test is fabricated in the form of a thin rod. A weak circular aperture coupling to the cavity is used to enhance the Q of the cavity. $\varepsilon_r = \varepsilon_r' - j\,\varepsilon_r''$ is the relative complex permittivity. The real and imaginary parts of the relative permittivity are calculated from measurable quantities as follows:[2]

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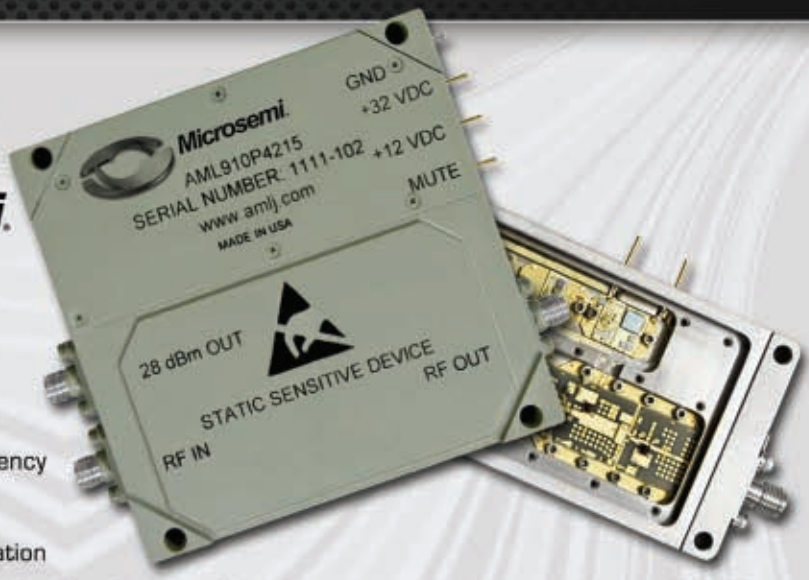

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AML13P5013	1.0 - 3.0	50	46	47	50	28V, 4.8A	25%	EAR99
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AML811P5012	7.8 - 11.0	50	46	47	50	28V, 5.5A	30%	3A001.b.4.b
AML811P5013	7.8 - 11.0	50	48	49	80	28V, 11.5A	25%	3A001.b.4.b
AML1416P4511	14.0 - 16.0	45	42	43	20	35V, 3.2A	18%	ITAR
AML1416P4512	14.0 - 16.0	45	45	46	40	35V, 6.2A	18%	ITAR
AML618P4014	6.0 - 18.0	40	39	40	10	32V, 2.8A	12%	ITAR
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AML218P4012	2.0 - 18.0	35	37	38	6	32V, 1.5A	13%	ITAR
AML218P4011	2.0 - 18.0	40	39	40	10	32V, 2.8A	12%	ITAR
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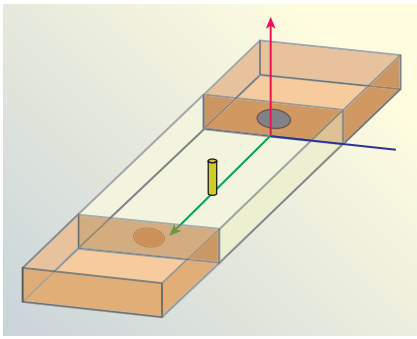

Fig. 1 Cavity resonator.

$$\varepsilon_r' = \left[V_c\left(f_c - f_s\right)/2V_s f_s\right] + 1 \quad (1)$$

$$\varepsilon_r'' = \left[V_c/4V_s\right]\left(1/Q_s - 1/Q_c\right) \quad (2)$$

$$Q_c' = Q_c\left[1 + \left(\varepsilon_r' - 1\right)\right]V_s/V_c \quad (3)$$

$$1/Q_d = \tan\delta = \varepsilon_r''/\varepsilon_r' \quad (4)$$

where f_c and f_s are the resonant frequencies without and with the sample, respectively, and Q_c and Q_s are the quality factors of the cavity without and with the sample inside the cavity, respectively, V_c and V_s are the volumes of cavity and the sample, respectively.

The rectangular X-Band waveguide cavity used in this work is shown in ***Figure 1***. The cavity is coupled to a WR90 (X-Band) waveguide through circular inductive irises at both ends of the cavity. The sample is inserted through a non-radiating hole at the center of the broad side of the cavity. The resonant frequency and Q of the cavity with and without the sample are measured and ε_r' and tan δ are computed from Equations 1 to 4. The Q is calculated from the following relation

$$Q = f_0/\left(f_2 - f_1\right) \quad (5)$$

where f_0 is the resonant frequency and f_2 and f_1 are the frequencies at the –3 dB points.

DESIGN METHODOLOGY

The measurement system, shown in ***Figure 2***, is composed of the following:

- HP 8510C Network Analyzer
- LabVIEW Version 8.2
- Computer with GPIB card
- TE_{103} cavity

The computer is interfaced with the network analyzer through the GPIB port. The cavity resonator is connected to the two ports of the HP

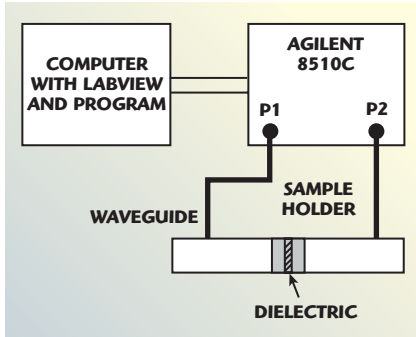

Fig. 2 Block diagram of the test set-up.

8510 S-parameter test set with standard waveguide to coax adaptors. The resonance properties, that is the resonant frequency and the 3 dB frequency points are observed with the VNA for the loaded and unloaded cavity.

The program for the measurement of dielectric constant and loss tangent using a VNA has been developed using LabVIEW, which controls every stage of the measurement process. The program performs the tasks of instrument control, data acquisition and post processing of data. The computer plays the roles of talker (writes a control string to the instrument with the address), listener (receive data string from the instrument with the address) and controller (GPIB). The devised program has a simple and user friendly input panel, where the details of the measurement set up like frequency range, number of points and dimensions of sample can be entered. The measured data and results are displayed in the output panel. The program flowchart is shown in ***Figure 3***. In designing this measurement software, a modular approach has been chosen. In LabVIEW, these modules are called virtual instruments (VI). The main VI, automated cavity perturbation (ACP) measurements, consists of various sub-VIs, which are designed for specific tasks as shown in ***Figure 4***. These sub-VIs can be executed and debugged independently. The functions of various sub-VI are as follows:

- Initialize.VI: This VI initializes the system by taking information from the input panel as start frequency, stop frequency, number of points, parameter and scale.
- –3 dB.VI: This VI measures the resonance frequencies and –3 dB points on either side of the resonance curve, first for the unloaded cavity as well as for the cavity loaded with the sample.
- Cal.VI: This VI calculates the dielectric parameters, that is the dielectric constant (ε_r') and loss tangent (tan δ) from the recorded data, using Equations 1 to 4.
- Plot_Gen.VI: This VI presents the resonance curves for the empty cavity and for the loaded cavity.
- Waveformgraph.VI: This is used to present the waveform in the desired format.

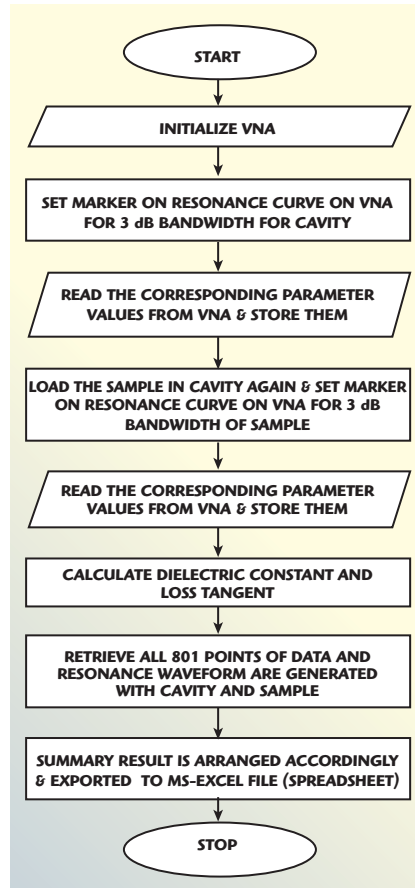

Fig. 3 Flow chart of the software.

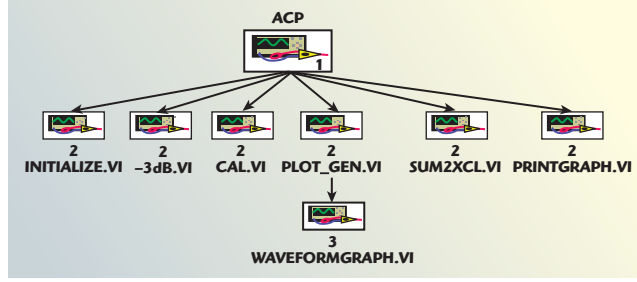

Fig. 4 Main VI and sub VIs.

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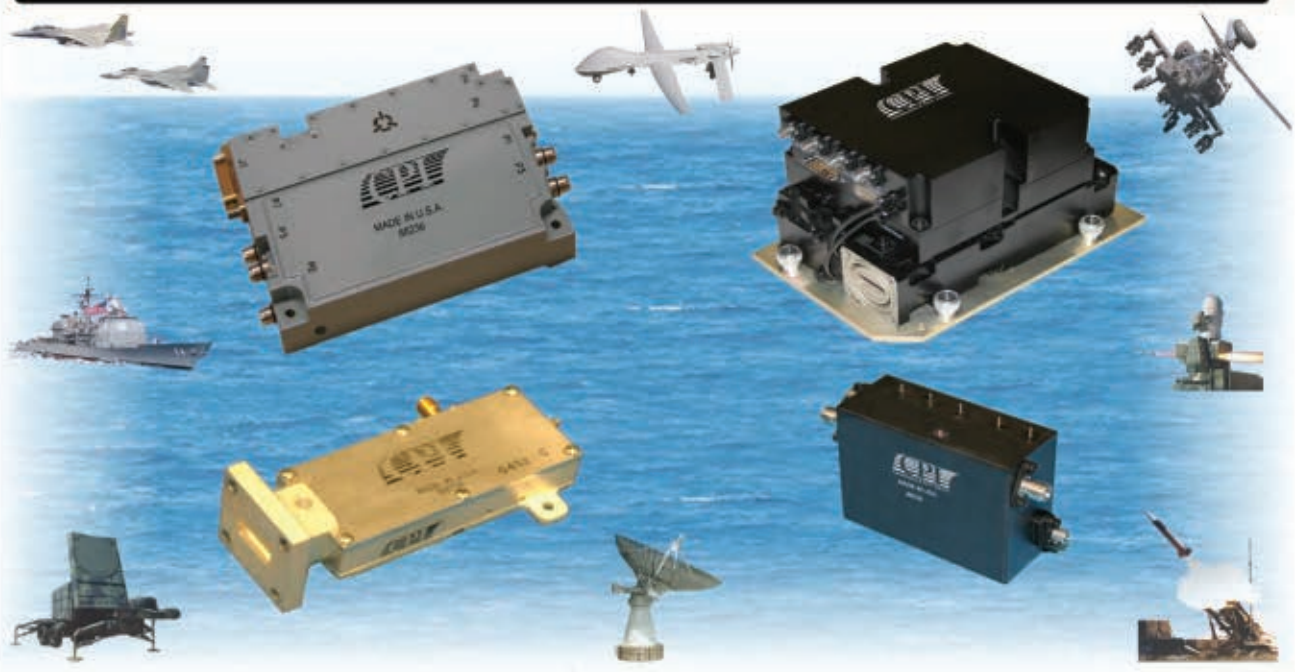

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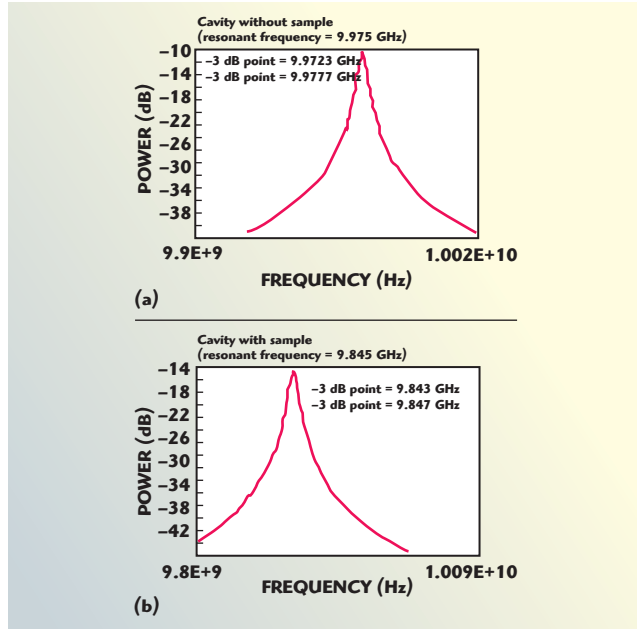

▲ *Fig. 5 Resonant frequency curves (a) unloaded cavity and (b) loaded cavity.*

- Sum2xcl.VI: This saves and presents the results in an EXCEL sheet.
- Printgraph.VI: This VI is used to print the graphs and provide a hard copy of the data.

Figure 5 shows the measured resonance curves for the unloaded cavity and the loaded cavity.

CONCLUSION

The software for automated measurement of dielectric constant and loss tangent of dielectric materials at X-Band, using a VNA and LabVIEW, has been successfully developed. The method is simple and flexible as the VIs can be adapted to meet changing requirements, if any, very quickly. The system is routinely used for our work on ceramic and ferrite. ■

ACKNOWLEDGMENT

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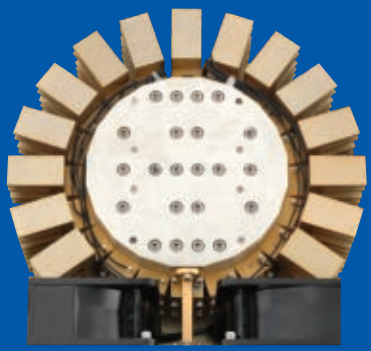
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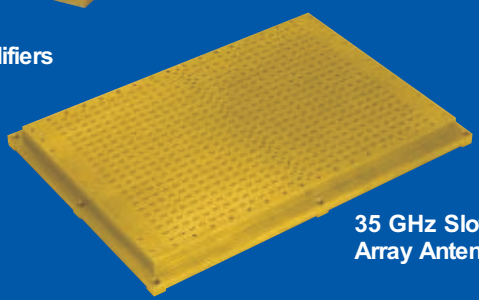
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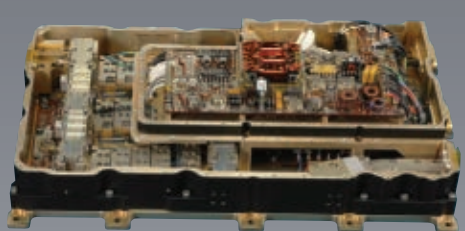
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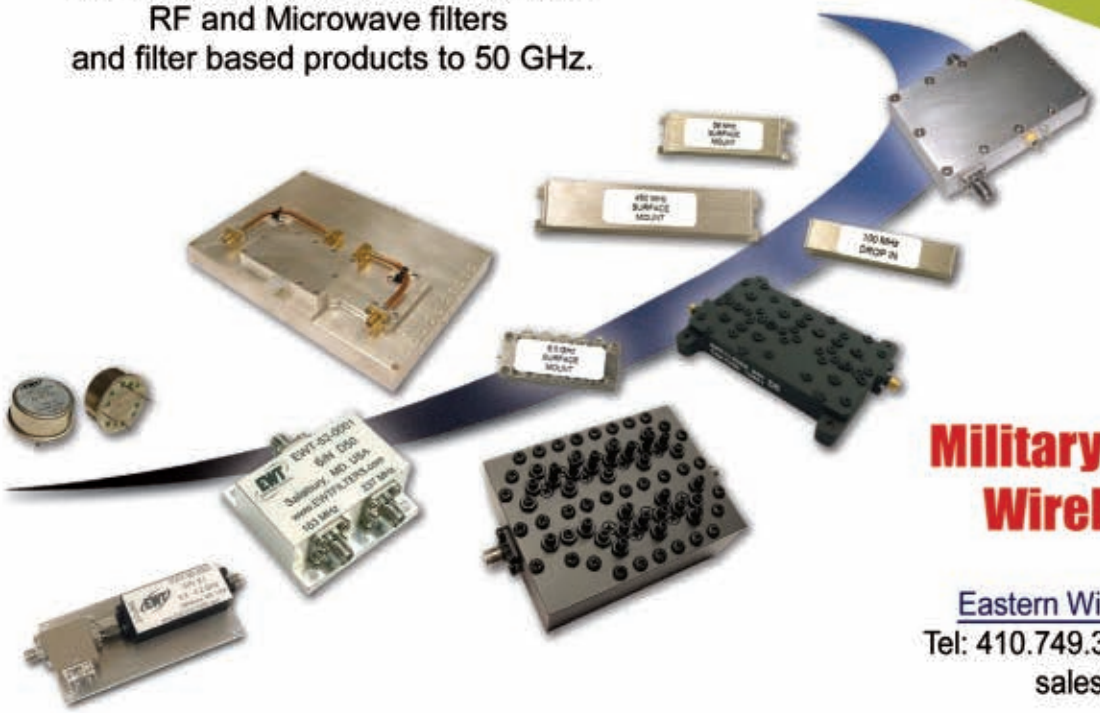

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IQ DEMODULATOR INTEGRATES PLL/ VCO TO REDUCE SYSTEM SIZE

Peter Real, Vice President of Analog Devices' Linear and RF group, discusses the company's new products and how Analog Devices opened up its laboratory expertise with the "Circuits from the Lab" series.

Executive Interviews

Integration to reduce system size, while still maintaining performance levels achieved by discrete solutions has been a main focus across multiple industries. Recently, Analog Devices developed a series of highly integrated IQ demodulators with a fractional-N phase locked loop (PLL), a voltage-controlled oscillator (VCO), and multiple low drop-out regulators (LDO) into a compact 40-lead 6 × 6 mm LFCSP package. The RFICs leverage SiGe BiCMOS technology to achieve this small size without sacrificing electrical performance.

The ADRF680X family uses a high performance mixer core that results in an exceptional input IP3 and input P1dB, with a very low output noise floor for excellent dynamic range, along with a low noise VCO, combined to achieve an excellent error vector magnitude (EVM). The three devices in the ADRF680X family support LO frequency ranges from 50 to 1150 MHz to cover a wide range of IF frequencies used in QAM/QPSK receivers as well as supporting common cellular standards, such as W-CDMA/CDMA2000/LTE, and also microwave point-to-point and point-to-multipoint radio architectures. The ADRF680X family also features multiple programmable functions through its SPI port. This allows the user to control the fractional-N PLL, the demodulator LO divider, multiple optimization options, low power mode, as well as allowing for an externally applied LO, or to generate a divided-down VCO signal for external use. The ADRF680X family is the only known quadrature demodulators to combine three RF functions into a single device, thereby simplifying design and reducing board space and bill of materials cost.

The newest member of the ADRF680X family is the ADRF6806, ***Figure 1***. It uses a differential RF input and operates over an LO frequency range of 50 to 525 MHz. The differential I and Q output paths have excellent quadrature performance with a phase accuracy of $<0.5°$ and amplitude accuracy of < 0.1 dB and can handle baseband signaling or complex IF up to 120 MHz. The ADRF6806 has an in-

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put P1dB of 12.2 dBm, an input IP3 of 28.5 dBm, a noise figure (DSB) of 12.2 dB, a voltage conversion gain of 1 dB, and a wide 3 dB baseband demodulation bandwidth of 170 MHz. When the part is run in low power mode to reduce current consumption, the ADRF6806 has an input P1dB of 10.6 dBm, an input IP3 of 25.2 dBm, a noise figure (DSB) of 11.4 dB, a voltage conversion gain of 4.2 dB, and a 3 dB baseband demodulation bandwidth of 135 MHz.

The next member of the ADRF680X family is the higher frequency ADRF6807. It also uses a differential RF input and operates over an LO frequency range from 700 to 1050 MHz. The differential I and Q output paths have excellent quadrature performance with a phase accuracy of < 0.5° and amplitude accuracy of < 0.1 dB and can handle baseband signaling or complex IF up to 120 MHz. The ADRF6807 has an input P1dB of 12.8 dBm, an input IP3 of 26.7 dBm, a noise figure (DSB) of 13.1 dB, a voltage conversion gain of 1 dB, and a wide 3 dB baseband demodulation bandwidth of 170 MHz. When the part is run in low power mode to reduce current consumption, the ADRF6807 has an input P1dB of 11.7 dBm, an input IP3 of 24 dBm, a noise figure (DSB) of 12.4 dB, a voltage conversion gain of 4.3 dB, and a 3 dB baseband demodulation bandwidth of 135 MHz.

Next is the single-ended 50 Ω input ADRF6801, that operates over an LO frequency range of 750 to 1150 MHz. The differential I and Q output paths have excellent quadrature performance with a phase accuracy of 0.3° and amplitude accuracy of 0.05 dB and can handle baseband signaling or complex IF up to 120 MHz. The ADRF6801 has an input P1dB of 12.5 dBm, an input IP3 of 25 dBm, a noise figure (DSB) of 14.3 dB, a voltage conversion gain of 5.1 dB, and a wide 3 dB baseband demodulation bandwidth of 275 MHz.

To evaluate overall demodulator performance, the EVM versus RF input power was analyzed. EVM is a measurement used to quantify the performance of a digital radio transmitter or receiver. A signal received by a receiver has all constellation points at their ideal locations. However, various imperfections in the receiver signal chain, such as magnitude imbalance, noise floor, and phase imbalance cause the actual constellation points to deviate from their ideal locations.

In general, a demodulator exhibits three distinct EVM limitations versus received input signal power. As signal power increases, the distortion components increase. At large enough signal levels, where the distortion components due to the harmonic nonlinearities in the device are falling in-band, EVM degrades as signal levels increase. At medium signal levels, where the demodulator behaves in a linear manner and the signal is well above any notable noise contributions, the EVM has a tendency to reach an optimal level determined dominantly by either quadrature accuracy and I/Q gain match of the demodulator or the precision of the test equipment. As signal levels decrease, such that the noise is a major contribution, the EVM performance versus the signal level exhibits a decibel-for-decibel degradation with decreasing signal level. At lower signal levels, where noise proves to be the dominant limitation, the decibel EVM proves to be directly proportional to the SNR.

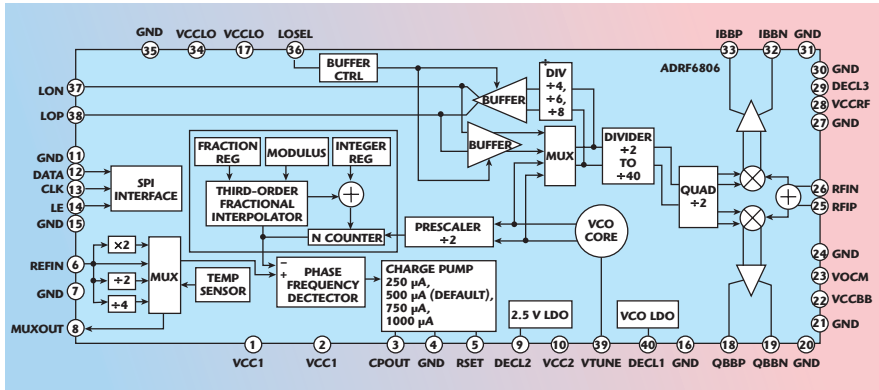

Fig. 1 ADRF6806 block diagram and pin outs.

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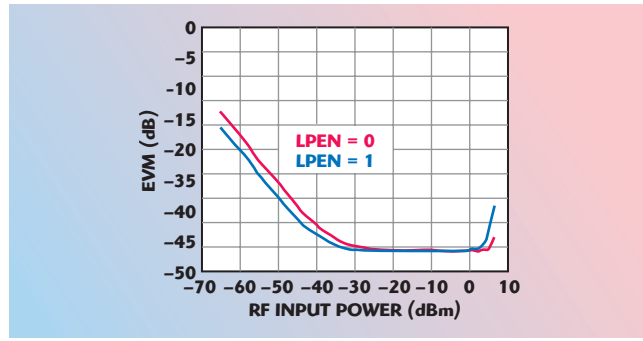

Fig. 2 EVM performance of ADRF6806 for a 16 QAM modulated signal.

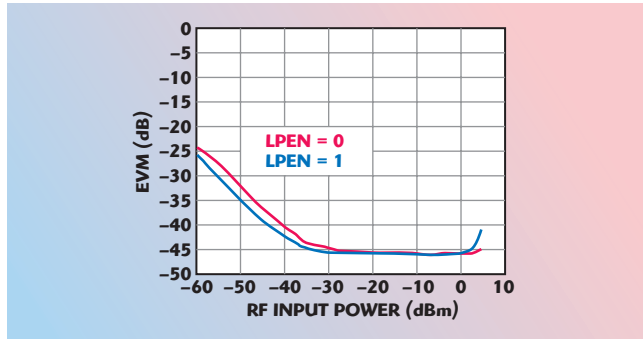

Fig. 3 Peak EVM of ADRF6806 for a 256 QAM modulated signal.

A 140 MHz modulated signal was used to test the EVM of the ADRF6806 on its evaluation board, and the ADRF6806 shows excellent EVM performance for various modulation schemes. ***Figure 2*** shows the EVM of the ADRF6806 being better than –45 dB over a wide RF input range of about +35 dB for a 16 QAM modulated signal at a 5 MHz symbol rate with a baseband IF of 5 MHz. EVM was tested for both power modes: normal power mode, LPEN 0, and low power mode, LPEN = 1. When low power mode is enabled, the EVM is better at lower RF input signal levels due to the parts' lower noise. While in normal power mode the EVM remains lower at higher RF input signal levels.

Figure 3 shows the peak EVM of the ADRF6806 for a 256 QAM modulated signal that is not degraded with respect to the previously shown 16 QAM signal results. The symbol rate was also 5 MHz with a baseband IF of 5 MHz. Again, EVM was tested for both power modes and is better than –45 dB over a wide RF input power range of about +35 dB.

The ADRF680X family provides very high levels of integration and performance by incorporating a high dynamic range mixer core, a versatile fractional-N PLL, a low noise VCO, and multiple LDOs. Packaged in a compact 40-lead 6 × 6 mm LFCSP, it delivers exceptional dynamic range and EVM performance required of today's demanding receiver architectures.

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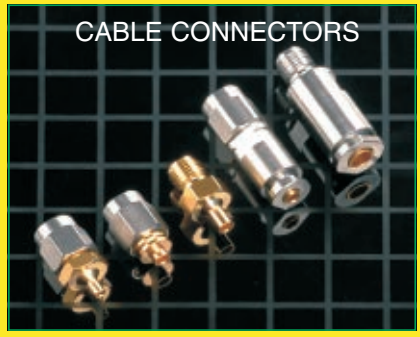

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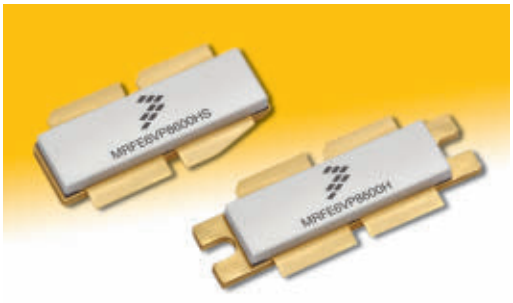

EXTREMELY RUGGED UHF 600 W LDMOS TRANSISTORS

Recently, Freescale Semiconductor developed two new LDMOS power transistors that are setting new standards for ruggedness in the UHF broadcast transmitter industry and ISM applications. The MRFE6VP8600H and MRFE6VP8600HS are push-pull power transistors, which provide enhanced RF performance while operating over the entire 470 to 860 MHz UHF frequency band. When used in digital UHF TV applications (such as DVB-T), these devices will deliver highly linear, 125 W average signal output power at 30 percent efficiency. In addition, these two transistors are fully capable of sustained power output (CW) greater than 600 W (P1dB). More importantly, at full-rated output power the devices will not degrade in performance even while withstanding a nearly 100 percent mismatched load (greater than 65:1 VSWR) at all phase angles. This unmatched ruggedness specification holds true even when the transistors are over-driven at up to twice their rated input power, as can often be encountered with digital pre-distortion (DPD) systems. Finally, with over 19 dB of gain across the band, the MRFE6VP8600H and MRFE6VP8600HS provide a combination of excellent linear power amplification, high efficiency and ruggedness for the broadcast transmitter industry.

SIMPLIFYING UHF TRANSMITTER DESIGN

Taken together, the high output power and high gain capabilities of the MRFE6VP8600H will mean a reduction in the total number of splitters, transistors and combiner stages needed for a given output power level. This helps to simplify the transmitter design and improve reliability when compared to previous generation solid-state UHF amplifier systems. In ***Figure 1***, a representative UHF amplifier consists of four MRFE6VP8600H transistors driven by

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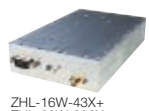
Model *With Heat Sink/Fan*	Freq. (MHz) fL-fU	Gain (dB) Typ.	Pout (dBm) @Comp 1dB Typ.	Pout (dBm) @Comp 3dB Typ.	Dynamic Range NF (dB) Typ.	Dynamic Range IP3 (dBm) Typ.	DC Pwr. Volt (V) Nom.	DC Pwr. Current (A) Max	Price $ ea. Qty. 1-9	Price *X suffix*
NEW LZY-22+	0.1-200	43	+42.0	+45.0	8.9	+52	24	6.0	1495	1470
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-30W-262+	2300-2550	50	+43.0	+45.0	7.0	+50	28	4.3	1995	1920
• 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
• ZHL-100W-GAN+	20-500	42	+49.0	+50.0	7.0	+60	30	9.5	2395	2320
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

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

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



ZHL-16W-43X+
ZHL-30W-252X+
ZHL-30W-262X+

ZHL-5W-1X
ZHL-5W-2GX+

LZY-1X+
LZY-2X+
LZY-22X+
ZHL-10W-2GX
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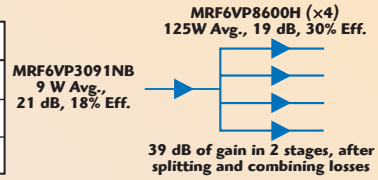
U.S. Patents 7739260, 7761442

IF/RF MICROWAVE COMPONENTS

TYPICAL PERFORMANCE: WIDEBAND 470 TO 860 MHz

DEVICE	MRF6VP3091NB	MRFE6VP8600H (X4)	COMBINED TOTAL
TYPICAL GAIN (dB)	21	19	39
AVERAGE P_{out} (W)	9	125	450
DRAIN EFFICIENCY (%)	18	30	26

5 total parts, DVB-T (8k OFDM) signal



▲ *Fig. 1 UHF TV amplifier design using one MRF6VP3091NB and four MRFE6VP8600H devices with 450 W average output power.*

TABLE I

KEY PRODUCT FEATURES FOR THE MRFE6VP8600H AND MRFE6VP8600HS LDMOS POWER TRANSISTORS

- Enhanced Ruggedness: Devices can withstand > 65:1 VSWR load mismatch with no damage (over all phase angles and with 3 dB overdrive)
- 19 dB gain at 860 MHz, DVB-T
- Deliver 125 W Avg. DVB-T (8k OFDM) output power at 50 V supply
- P1dB is greater than 600 W over the entire 470 to 860 MHz UHF band
- Efficiency is typically 30 percent (and up to 45 percent in Doherty configuration)
- Extended negative gate-source voltage range (-6 to +10 V)
- Integrated ESD protection
- Characterized for extended operating range from 20 to 50 V means these transistors are fully compatible for use with enhanced drain supply modulation schemes, such as envelope tracking
- Optimize just one transistor for many different UHF amplifier designs: These transistors can be easily designed into Class AB, Doherty, or drain modulation amplifier architectures, so there is no need to waste valuable design resources optimizing different output-stage devices for each individual amplifier design

a single MRF6VP3091NB amplifier, resulting in 450 W average DVB-T output power at a combined 26 percent power-added-efficiency (PAE) – including all five devices.

REDUCE MONTHLY COSTS FOR BROADCASTERS

Each MRFE6VP8600H transistor by itself is capable of around 30 percent output power efficiency, so less overall current is required and less power is wasted as heat (for a given power output), translating directly into monthly utility cost savings for the UHF broadcaster. At 30 percent output-stage efficiency, a solid-state transmitter design based on the MRFE6VP8600H can use up to 15 percent less power than previous generations. When used in Doherty amplifier configurations, the overall output-stage efficiency can increase to approximately 45 percent, saving additional monthly utility costs. Still further PAE improvements are possible using amplifier drain modulation schemes (such as envelope tracking).

EXTENDED NEGATIVE GATE-SOURCE VOLTAGE RANGE

The MRFE6VP8600H includes an extended negative gate-source voltage range from –6 to +10 V. This unique feature allows improved Class C operation, such as when the device is used as the peaking stage of a Doherty amplifier. This feature can also be used to provide an easy way to safely, quickly and completely shut down the amplifier.

REDUCTIONS IN TRANSMITTER PARTS COUNT

The broadband internal input matching circuit included within the MRFE6VP8600H reduces the external component count, simplifies circuit design and results in better power distribution across multi-stage amplifiers (see Figure 1). In addition, the enhanced ruggedness characteristics of the MRFE6VP8600H make it possible to design an amplifier with more simplified transmitter protection circuitry, even eliminating the need for isolators and/or circulators in many applications.

ROBUST DESIGN AND IMPROVED PERFORMANCE

Given their enhanced ruggedness, the MRFE6VP8600H/HS devices can tolerate the out-of-band reflective load conditions caused by highly selective channel filters and the high peak-to-average (PAR) of the newest digital transmission schemes. This is especially true for higher-order modulation techniques such as the DVB-T and DVB-T2 standards. In addition, the enhanced ruggedness makes the MRFE6VP8600H/HS far more reliable under adverse conditions (such as operator error, transmission line failure, antenna icing), even with the higher drive peaks normally associated with today's pre-distortion systems. ***Table 1*** summarizes the key features of these devices.

Typical applications for the MRFE6VP8600H/HS include all digital UHF television transmitters, translators and gap fillers employing DVB-T, DVB-T2, ATSC, or ISDB-T standard modulation schemes. The devices are also well-suited for use in analog UHF television transmitter designs. In addition, the MRFE6VP8600H and MRFE6VP8600HS can be used for many Industrial, Scientific and Medical (ISM) applications over the entire frequency range of 450 to 900 MHz.

Finally, these rugged LDMOS transistors have been designed and tested to provide high reliability, and either device is capable of providing an extended working life even in the most demanding environments. RF amplifier designers can choose either air-cavity ceramic package – the bolt-down NI-1230 or the solder-attach NI-1230S.

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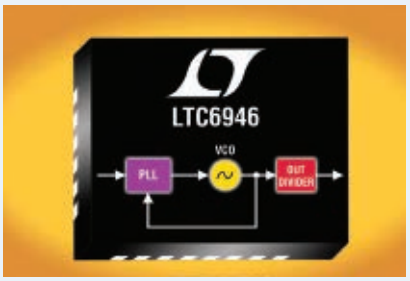
www.richardsonrfpd.com.



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Linear Technology has developed the LTC6946, the first device in a family of high performance integer-N frequency synthesizers with integrated VCO, delivering –226 dBc/Hz normalized closed-loop in-band phase noise, –274 dBc/Hz normalized in-band 1/f noise and best-in-class –103 dBc spurious output. In a typical 900 MHz application, these performance attributes help to achieve a closed-loop phase noise of –100 dBc/Hz at 1 kHz offset. The device is available in three frequency options: the LTC6946-1 tunes from 2.240 to 3.740 GHz; the LTC6946-2 from 3.080 to 4.910 GHz; and the LTC6946-3 from 3.840 to 5.790 GHz. In addition, each part has an on-chip output divider that is programmable from 1 through 6 to extend frequency coverage to as low as 373 MHz.

This family of devices integrates a low noise 5.7 GHz phase-locked loop (PLL), which includes a reference divider, phase-frequency detector (PFD) with phase-locked indicator, ultralow noise charge pump, and integer feedback divider to attain very low noise PLL operation. The PLL circuit is tightly coupled to a low noise VCO as well as internal self-calibration to ensure optimum VCO resonator tuning for best phase noise performance. The VCO requires no external components. The on-chip SPI compatible bidirectional serial port allows frequency tuning and control, and read back of register and loop status information. All versions of the LTC6946 are specified over the full case temperature range from –40° to 105°C. The products are available in a 4 × 5 mm, 28-lead plastic QFN package.

The low phase noise and spurious capabilities of this family of frequency synthesizers enhance the performance of multiband base stations supporting LTE, W-CDMA, UMTS, CDMA, GSM and WiMAX standards. Its high frequency capability also supports point-to-point broadband wireless access, military, avionics, and high performance test and measurement applications.

Linear Technology, Milpitas, CA (408) 432-1900, www.linear.com.

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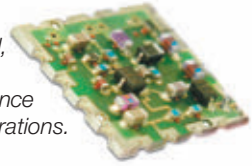

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DCO Series					
DCO50100-5	500 - 1000	0.5 - 15	+5 @ 34 mA	-100	0.3 x 0.3 x 0.08
DCO6080-3	600 - 800	0 - 3	+3 @ 15 mA	-105	0.3 x 0.3 x 0.08
DCO7075-3	700 - 750	0.5 - 3	+3 @ 12 mA	-108	0.3 x 0.3 x 0.08
DCO80100-5	800 - 1000	0.5 - 8	+5 @ 26 mA	-111	0.3 x 0.3 x 0.08
DCO8190-5	810 - 900	0.5 - 16	+5 @ 34 mA	-118	0.3 x 0.3 x 0.08
DCO100200-5	1000 - 2000	0.5 - 24	+5 @ 36 mA	-95	0.3 x 0.3 x 0.08
DCO1198-8	1195 - 1205	0.5 - 8	+8 @ 30 mA	-115	0.3 x 0.3 x 0.08
DCO170340-5	1700 - 3400	0.5 - 24	+5 @ 29 mA	-90	0.3 x 0.3 x 0.08
DCO200400-5 DCO200400-3	2000 - 4000	0.5 - 18	+5 @ 46 mA +3 @ 46 mA	-90 -89	0.3 x 0.3 x 0.08
DCO300600-5 DCO300600-3	3000 - 6000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-80 -78	0.3 x 0.3 x 0.08
DCO400800-5 DCO400800-3	4000 - 8000	0.5 - 18	+5 @ 20 mA +3 @ 20 mA	-78 -76	0.3 x 0.3 x 0.08
DCO432493-5 DCO432493-3	4325 - 4950	0.5 - 11	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.08
DCO473542-5 DCO473542-3	4730 - 5420	0.5 - 22	+5 @ 20 mA +3 @ 20 mA	-88 -86	0.3 x 0.3 x 0.08
DCO490517-5 DCO490517-3	4900 - 5175	0.5 - 5	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.08
DCO495550-5 DCO495550-3	4950 - 5500	0.5 - 12	+5 @ 22 mA +3 @ 22 mA	-83 -85	0.3 x 0.3 x 0.08
DCO579582-5	5780 - 5880	0.5 - 10	+5 @ 20 mA	-90	0.3 x 0.3 x 0.08
DCO608634-5 DCO608634-3	6080 - 6340	0.5 - 5	+5 @ 20 mA +3 @ 26 mA	-85 -86	0.3 x 0.3 x 0.08
DCO615712-5 DCO615712-3	6150 - 7120	0.5 - 18	+5 @ 22 mA +3 @ 22 mA	-85 -83	0.3 x 0.3 x 0.08

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

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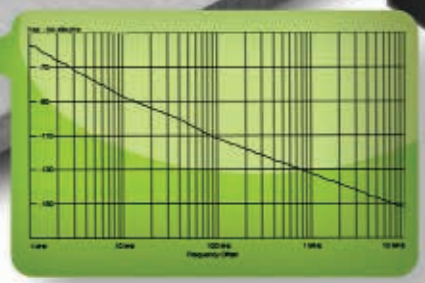

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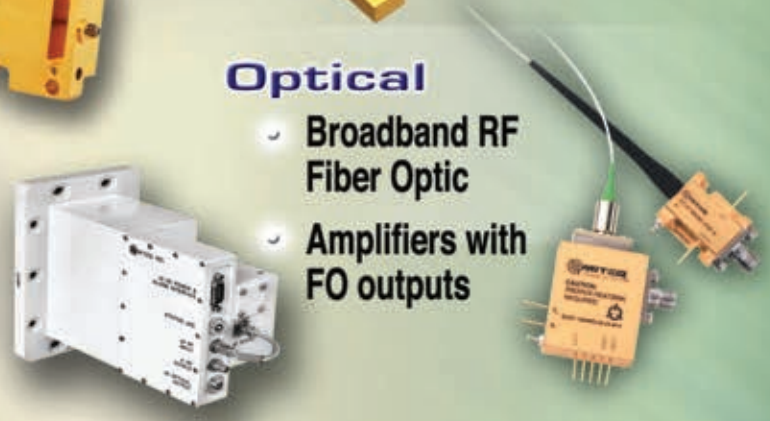

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RWW 2012 Highlights

IEEE Radio and Wireless Symposium
IEEE Topical Conference on Wireless Sensors and Sensor Networks
IEEE Topical Conference on Biomedical Wireless Technologies, Networks & Sensing Systems
IEEE Topical Conference on RF/microwave Power Amplifiers
Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems

32 Technical Oral Sessions - Mon - Wed, 16-18, Jan., 2012
Poster Sessions - Mon - Wed, 16-18, Jan., 2012
Demo Sessions - More details soon!
Student Paper Competition Finals - More details soon!
Workshops - Sunday afternoon, 15, Jan., 2012
- "National & International Spectrum Management Policies and Processes for Wireless Professionals"
- "Advances of Nanoelectronics in RF Technology"
- "Telemedecine: Wireless Sensor and Body Area Networks"
- "Wireless Sensor Network Technologies for the Internet of Things"

Panel Session
- "Spectrum Sharing and Frequency Reuse"

Rump Session
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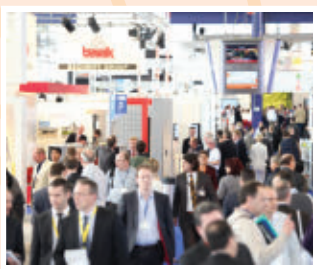
- 1,700 - 2,000 conference delegates
- In excess of 250 exhibitors

Running alongside the exhibition are 3 separate, but complementary Conferences:

- European Microwave Integrated Circuits Conference (EuMIC)
- European Microwave Conference (EuMC)
- European Radar Conference (EuRAD)

Plus a one day Defence and Security Conference



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SPDT Coaxial Switch

The 2EL Series SPDT coaxial switches features SMA connectors and operates at a frequency range from DC to 18 GHz and the 2ELE Series operates at DC to 26.5 GHz. Both series are available with failsafe and latching self cut-off options. Operating life is 5,000,000 cycles typical (3,000,000 minimum). RF impedance is 50 Ω nominal. Operating temperature (failsafe) is -55° to +85°C ambient. Operating temperature (failsafe) is -25° to +85°C ambient. Switching sequence is break before make. Ducommun has design engineers who can create custom versions for specific applications.

Ducommun LaBarge Technologies,
Carson, CA
(310) 513-7200,
www.ducommun.com.

800 W Termination

VENDORVIEW

Florida RF Labs has introduced a high performance, flange mounted, 800 W termination. The 32M7200F offers outstanding performance and low VSWR and the convenience of bolt on installation. This termination has been optimized for performance in the DC to 0.5 GHz frequency range, boasting a 1.10:1 maximum VSWR, making it very appealing to the broadcast, public safety and medical (MRI) markets. This termination offers high power, integrated heat sink, and tab launch. This new 800 W termination exhibits excellent thermal characteristics through a superb heat distribution design. The package size is 1.900" (456.26 mm) × 1.040" (26.42 mm) and delivered in a tray package. This product is also non-magnetic and RoHS and REACH compliant. The 32M7200F datasheet and evaluation samples are readily available upon request.

Florida RF Labs,
Stuart, FL
(772) 600-1632,
www.emc-rflabs.com.

Octal ADCs

VENDORVIEW

Hittite Microwave Corp. is featuring a new set of octal 12-bit analog-to-digital converters, the HMCAD1102, HMCAD1101 and HMCAD1100. They complement Hittite's ultra low power ADC products. The HMCAD1102, HMCAD1101 and HMCAD1100 family are octal 12 and 13-bit ADCs that operate from 20 to 80 MSPS. Both 12-bit and 14-bit LVDS output modes are available and can be selected through the SPI control interface. Noise performance (SNR) at 50 MSPS with 8 MHz input frequency and 14-bit output is typically 72.2 dB. It is PIN compatible with the ADS527x and ADS528x families from Texas Instruments. Power dissipation at 50 MSPS is 40 mW per channel, including LVDS outputs. The ADCs are housed in a 9 × 9 mm plastic leadless surface-mount package and provide excellent temperature stability over the -40° to +85°C temperature range. Samples and evaluation PC boards for all SMT packaged products are available from stock and can be ordered via the company's e-commerce site or via direct purchase order.

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

ISM Band Cavity Filter

VENDORVIEW

NIC introduces a 902 to 928 MHz cavity filter offering high performance for ISM base station applications. This filter provides low insertion loss of < 1.5 dB and 45 dB rejection in the cellular band of 824 to 894 MHz and GSM band of 936 to 960 MHz. Features include high performance, competitive pricing and fast delivery. Prototypes are available for immediate delivery. Custom configurations designed up to Ku-Band.

Networks International Corp.,
Overland Park, KS
(913) 685-3400,
www.nickc.com.

Low Noise Amplifier

NuWaves Engineering has expanded its series of High Intercept Low Noise Amplifiers (HILNA™) with the introduction of the HILNA 3G. NuWaves' HILNA 3G is the latest addition to the family of low noise, high gain, high intercept and wideband amplifiers. The HILNA 3G covers the broad frequency range from 1 to 3 GHz with a gain of 50 dB, and is even smaller than its predecessors, boasting a total of 3.3 cubic inches and weighing only 3 ounces. The HILNA 3G is ideal for system integration where footprint, high gain and broadband operation are determining factors. NuWaves' robust high performance amplifiers have been completely characterized over temperature, supply voltage, and frequency, in order to meet the demanding needs required in state-of-the-art RF systems.

NuWaves Engineering,
Middletown, OH
(513) 360-0800,
www.nuwaves-ltd.com.

PIN Diode

VENDORVIEW

Skyworks Solutions Inc. introduced SMP1345-087LF, a high power, series PIN diode for large signal transmit and receive switching applications. This high thermal-dissipative diode combines low insertion loss, very good isolation, fast switching, excellent power handling and low distortion in a very small surface-mount package. This diode is ideal for infrastructure, homeland security, first responder and military markets. Samples are available, and pricing depends on quantities.

Skyworks Solutions Inc.,
Woburn, MA (781) 376-3000,
www.skyworks.com.

Miniature Microwave Coax Contact Assemblies

Southwest Microwave Inc. announced miniature microwave coax contact assemblies that fit into the small, standard size 20 contact cavities of D-subminiature connectors and also size 20 (and larger) contact cavities for standard MIL-DTL-38999 circular connectors. Called SSBP-20, they can be used interchangeably with non-coax signal contact assemblies. Applications range from airborne to medical and test, from missile and space to mobile communications. Benefits include miniaturization, increased reliability and reduced system costs. Resistant to vibration (tested to 2000 Hz, random and sine, at 150°C) and shock (tested 3 axis, 100 Gs), yet installed with simple plastic tools. Although targeted for miniaturized packaging benefits, the interface is 0.9 mm, which permits economical use at both RF and extreme millimeter-wave applications and combinations thereof in the same connector. All Southwest Microwave interconnect products are RoHS compliant, lead free, with DFARS steel and raw material traceability.

Southwest Microwave Inc.,
Tempe, AZ (480) 783-0201,
www.southwestmicrowave.com.

Directional / Bi-Directional

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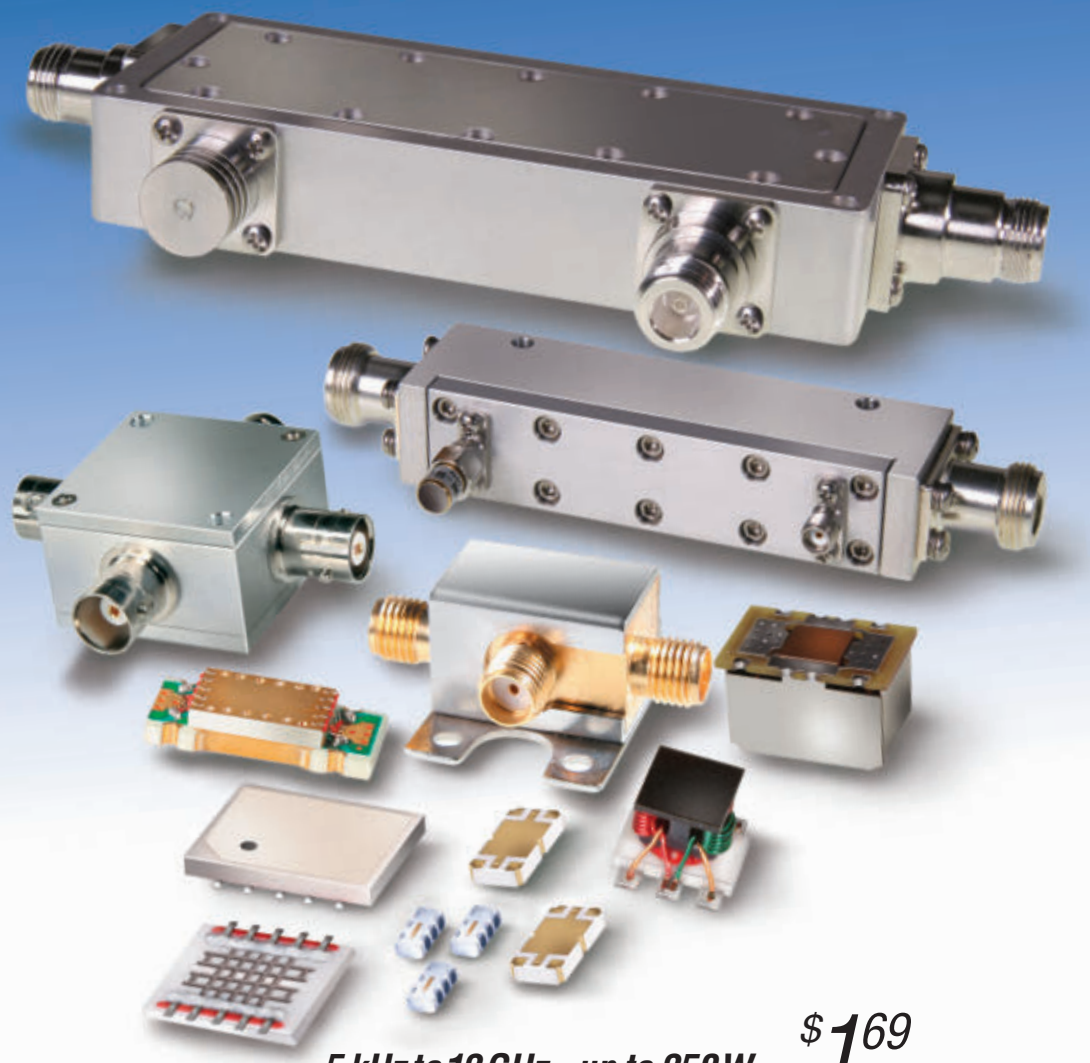

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At the other end of the scale, our new connectorized air-line couplers can handle up to 250W and frequencies as high as 12 GHz, with low insertion loss (0.2 dB @ 9 GHz, 1 dB @ 12 GHz) and exceptional coupling flatness! All of our couplers are RoHS compliant. So if you need a 50 or 75 Ω, directional or bi-directional, DC pass or DC block coupler, for military, industrial, or commercial applications, you can probably find it at minicircuits.com, and have it shipped today!

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Components

Point of Load Converters

Crane Aerospace & Electronics announced the availability of its Interpoint MFP Series Point of Load Converters in qualified H and K level MIL-PRF-38534 versions. These highly flexible non-isolated MFP converters are now registered with the Defense Logistics Agency (DLA) in Radiation Hardness Assurance (RHA) levels of 30 krad and 100 krad. Guaranteed RHA performance levels for both Enhanced Low Dose Rate Sensitivity (ELDRS) and standard conditions can now be ordered to a Standard Microcircuit Drawing (SMD). The MFP Series are single output 16 W devices providing output voltages from 0.64 to 3.5 V from a source voltage of 3 to 6 V. These are 1.2" × 1.2," up to 90 percent efficiency and low noise, while requiring no external components.
Crane Aerospace & Electronics, Redmond, WA (203) 363-7300, www.craneco.com.

38 GHz Narrowband Cavity Filter

A 36 GHz narrowband cavity filter has been developed for a satellite application by K&L Microwave. The center frequency is 36 GHz with a relative 3 dB bandwidth of 34 to 38 GHz. Typical VSWR is 1.3:1 in and out over 34 to 38 GHz and the insertion loss is less than 3 dB mid-band. The rejection is greater than 50 dB at 32 GHz. Impedance is 50 Ω and is available with K type connectors. The approximate size is 1.13" × 0.5" × 0.5" (without connectors).

K&L Microwave Inc., Salisbury, MD (410) 749-2424, www.klmicrowave.com.

Micro Miniature SMA Switch

RLC Electronics' Micro Miniature SMA switch is a single-pole, two-position type. The switch incorporates SMA connectors to allow high density packaging and excellent electrical performance through 26.5 GHz. The switch is available in failsafe and pulse latching configurations with a choice of three different frequency ranges and three different coil voltages.
RLC Electronics Inc., Mt. Kisco, NY (914) 241-1334, www.rlcelectronics.com.

High Isolation Switch

Telemakus released the TES7000-50 SPDT, USB-controlled switch that adds to the growing family of Telemakus test equipment. Operating from 100 MHz to 7 GHz with < 3 dB insertion loss and 50 dB of isolation at 4 GHz, the TES7000-50 handles up to 24 dBm CW input power (29 dBm pulsed). A built-in pulse function allows menu selectable pulse width and period from 250 nSec to 8 Sec. SMA connectors complement the full line of Telemakus USB-controlled devices providing the ability to cascade multiple accessories into a customized configuration to meet various requirements. Flash memory contains all necessary installation files for Windows XP or Vista. One of the smallest USB-controlled switches on the market, it weighs less than 1 ounce and can be carried in a pocket or tool box.
Telemakus Stocking Distributor RFMW Ltd., San Jose, CA (408) 414-1450, www.rfmw.com.

Amplifiers

X-Band Miniature Amplifier

VENDORVIEW

The AGM-1005-15 is a miniature X-Band amplifier, which features High Reliability Screening to MIL-STD-883 as standard, and can be used in either connectorized or drop-in configuration. Covering the 8 to 12 GHz frequency range the amplifier runs from a +15 V DC supply to deliver over 18 dBm of linear power at typical gain of 12 dB and noise figure of 4 dB at +25°C. Gain flatness is ±0.75 dB maximum over the band and the input and output VSWRs are 2.0:1 maximum. The amplifier utilizes thin film and MMIC technology to provide a versatile, economical and reliable gain module for microwave applications in communications, radar and defense equipment.
AtlanTecRF, Braintree, UK +44 (0)1376 550220, www.atlantecrf.com.

Low Noise Amplifier

The HLNAV-360 is a low noise amplifier with integrated isolators at the input and output ports. The LNA operates over the 57 to 64 GHz frequency band with 27 dB gain, noise figure of 6 dB and a P1dB of +12 dBm. RF interfaces are via WR-15 waveguide with standard UG-385/U flanges. A single MCX connector provides the bias input for the +15 V DC operating voltage. The amplifier bias is internally regulated and sequenced for reliability and user convenience. This same architecture can also be used for power amplifiers from 18 to 110 GHz. Bandwidths of 2 to 3 GHz are easily achieved, and bandwidths up to 7 GHz are available above 50 GHz.
HXI LLC, Harvard, MA (978) 772-7774, www.hxi.com.

Dual Output Amplifier

Model AML618P5012 is a high efficiency dual (combined) input, dual output power amplifier operating over 6 to 18 GHz bandwidth. Amplifier delivers +31 dBm power at each output and is designed to operate up to +95°C base plate temperature. AML618P5012 is available with input power protection option up to 2 W CW. This design is available in a high density package with 3.5" × 1" × 0.3." RF connectors are SMP. The DC supply is +10 V at 2.2 amps.

Microsemi, Camarillo, CA (805) 388-1345, www.amlj.com.

Sources

CMOS Oscillator

Crystek Corp. has launched the CCHD-575, a new ultra-low phase noise CMOS oscillator providing a –168 dBc/Hz noise floor. Compact and powerful, the CCHD-575 is the industry's lowest-jitter clock oscillator in a 5 × 7.5 mm package. Crystek's CCHD-575 features a typical phase jitter of 82 fSec RMS at 100 MHz. Close-in phase noise is -90 dBc/Hz at 10 Hz, while its floor is at -168 dBc/Hz. The extremely low phase noise performance is very

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useful in applications such as: DACs, ADCs, low phase signal sources, and test and measurement. The CCHD-575 generates frequencies between 50 and 130 MHz. Its output driver is capable of driving ±24 mA, translating to a rise/fall time of ~600 ps at 100 MHz with a 15 pF load. Input supply voltage of 3.3 V DC consuming 15 mA of current is required. Extended temperature operating range of -40° to +85°C is also available.

Crystek Corp.,
Ft. Myers, FL (800) 237-3061,
www.crystek.com.

Multi-Octave Frequency Synthesizer

The SBC Series consists of frequency synthesizers that feature tuning steps of 1 Hz, and exceptionally low phase noise (-100 dBc/Hz at 10 KHz). The units are locked to a 10 MHz external reference and offers +7 dBm output power, -15 dBc harmonics and -60 dBc spurs. Options include external or internal references (10 to 500 MHz) and extended temperature ranges. The SBC Series is available in custom multi-octave frequency bands to 8 GHz. The SBC Series is ideally suited as a lab source for prototype and bench-top testing. The SBC-3000 operates from 400 to 3000 MHz. The SBC-5000 operates from 700 to 5000 MHz. The SBC-8000 operates from 5000 to 8000 MHz.

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

VCO for TV Broadcasting

VENDORVIEW

The ZX95-868+ is a VCO, designed to operate from 805 to 868 MHz for TV broadcasting application. The ZX95-868+ is built using Mini-Circuits' proven unibody construction (1.20" × 0.75" × 0.46"), which integrates the RF connectors with the case body to shield against unwanted signals and noise. Features include low phase noise (-116 dBc/Hz typical at 10 kHz offset), linear tuning sensitivity ratio of 1.2:1 typical and excellent pulling (0.03 MHz typical).

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

RoHS-Compliant VCO

Z-Communications Inc. announces a new RoHS-compliant VCO model SMV1365C-LF in L-Band. The SMV1365C-LF operates at 1265 to 1465 MHz with a tuning voltage range of 0.5 to 4.5 V DC. This VCO features a typical phase noise of -98 dBc/Hz at 10 KHz offset and a typical tuning sensitivity of 113 MHz/V. The SMV1365C-LF is designed to deliver a typical output power of 8 dBm at 5 V DC supply while drawing 21 mA (typical) over the temperature range of -40º to 85ºC. This VCO features typical second harmonic suppression of -15 dBc and comes in Z-Comm's standard SUB-L package measuring 0.3" × 0.3" × 0.08." It is available in tape-and-reel packaging for production requirements. The SMV1365C-LF is also ideal for automated surface-mount assembly and reflow. SMV1365C-LF is well suited for applications that require ultra low phase noise performance.

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

Test Equipment

Pulser Heads for HBTs

AMCAD Engineering has released a new pulser, also referred to as probe head, tailored for small-periphery transistor (HBTs and HEMT) pulsed IV measurements. This new pulser, AM223, has two embedded measurement units: one for currents lower than 20 mA, one for currents between 20 and 200 mA. The system consists of two independently operating power modes – pulsed or DC (continuous mode). The maximum average power delivered by the sensors output is 50 W in pulsed mode, or 80 W in DC mode. This specification is linked to the external power probes used. The voltage measurements on the two channels are carried out from the internal resistance of each channel. The current measurements are made using differential measurements at the terminals of the same internal resistance.

Maury Microwave Corp.,
Ontario, CA (909) 987-4715,
www.maurymw.com.

Phase Stable Cables

Test grade cables are a must for RF applications. The test cables serve as the extension of the equipments' test ports. They provide flexibility for measuring cable assemblies or other microwave devices. It is vital to system performance that they remain stable when subjected to environmental or mechanical stresses. Phase stable cables have triple shielding with low loss dielectric and high temperature jacketing to minimize the phase effects when flexed multiple times. The connectors are made of rugged stainless steel for extended attachment and feature a strain relief support designed for armoring as an option. RF Precision Products now offers such cables for applications up to 26.5 GHz. Test charts are included. Off the shelf lengths are 24", 36" and 48". Custom lengths are available.

RF Precision Products,
Division of RF Industries,
San Diego, CA (858) 549-6340,
www.rfp2.com.

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Biosphère, Environment Museum

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About the conference:

The IEEE Microwave Theory and Techniques Society's 2012 International Microwave Symposium (IMS2012) will be held on 17-22 June in Montréal, Canada as the centerpiece of Microwave Week. IMS2012 offers technical sessions, interactive forums, plenary and panel sessions, workshops, short courses, industrial exhibits, application seminars, historical exhibits, and a wide array of other technical and social activities including a guest program. Colocated with IMS2012 are the RFIC symposium (www.rfic2012.org) and the ARFTG conference (www.arftg.org), which comprise the Microwave Week 2012 technical program. With over 9,000 attendees and over 800 industrial exhibits of the latest state-of-the-art microwave products, Microwave Week is the world's largest gathering of Radio Frequency (RF) and microwave professionals and the most important forum for the latest and most advanced research in the area.

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Advanced RF MEMS

Edited by Stepan Lucyszyn

Radio frequency microelectromechanical systems (RF MEMS) can offer superior RF performance over more conventional solid-state electronic devices and can help to implement advancements within a broad range of applications, from ubiquitous smart sensor networks to mobile handsets. Moreover, they can substantially reduce the size, weight and cost of reconfigurable subsystems, making this an important enabling technology for the 21st century. *Advanced RF MEMS* is an up-to-date guide to the theory and applications of these devices. With detailed information about RF MEMS technology as well as its reliability and applications, this is a comprehensive resource for professionals, researchers and students alike.

The book reviews RF MEMS technologies and illustrates new techniques that solve long-standing problems associated with reliability and packaging. It also provides the information needed to incorporate RF MEMS into commercial products, describes current and future trends in RF MEMS and provides a perspective on industry growth. The book is well suited for those studying or working in RF and microwave circuits, systems, micro-fabrication and manufacturing, production management and metrology and performance evaluation.

The book has contributions from many well known experts in the field so it provides comprehensive coverage of the subject, including future trends. Using materials from all these sources, Steve Lucyszyn does a nice job of presenting the content in a coherent manner. Although the content is global, it is primarily European as the book is a bi-product of a Network of Excellence, called Advanced MEMS for RF and Millimeter-Wave Communications (AMICOM) funded by the EU with all the contributing authors being associated with the network. It is a recommended book for academics and practicing engineers.

To order this book, contact:

Cambridge University Press,
32 Avenue of the Americas,
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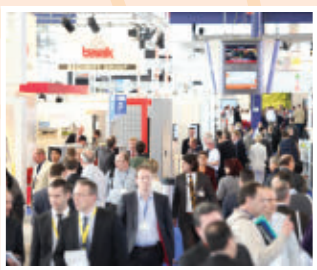

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Coming in January:

Radar and Antennas

- **The Changing Role of Microwave Technologies Inside Radar Systems**
- **FEBI Hybrid Method for Radar Systems Modeling**
- **Beyond Next Generation Mobile Broadband – BuNGee**
- **A Dual Band 3 dB Coupled Line Tandem Hybrid-Coupler**

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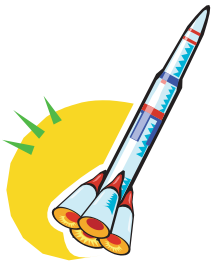
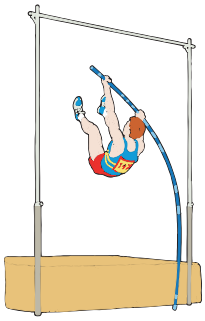


ROCKET LAUNCH

Why are the European Ariane rockets launched from the Korou site in French Guiana, South America, and not from some place in Europe where the rockets are built?

THE PZZLS EYE TEST

Close one of your eyes. Move your head close to the page and watch closely to the left circle if you closed your left eye. You should look to the right circle if you closed your right eye. Keep watching and move your head slowly backward while checking the other circle. What happens? And how is that possible?



POLE VAULTING

What is the maximum height a pole vaulter could theoretically jump? Would it ever be possible that a pole vaulter passes the height of 10 meters?

DAY AWAY

Sarah and Mike conclude that it is Wednesday. But five minutes later it is already Friday. How is that possible?

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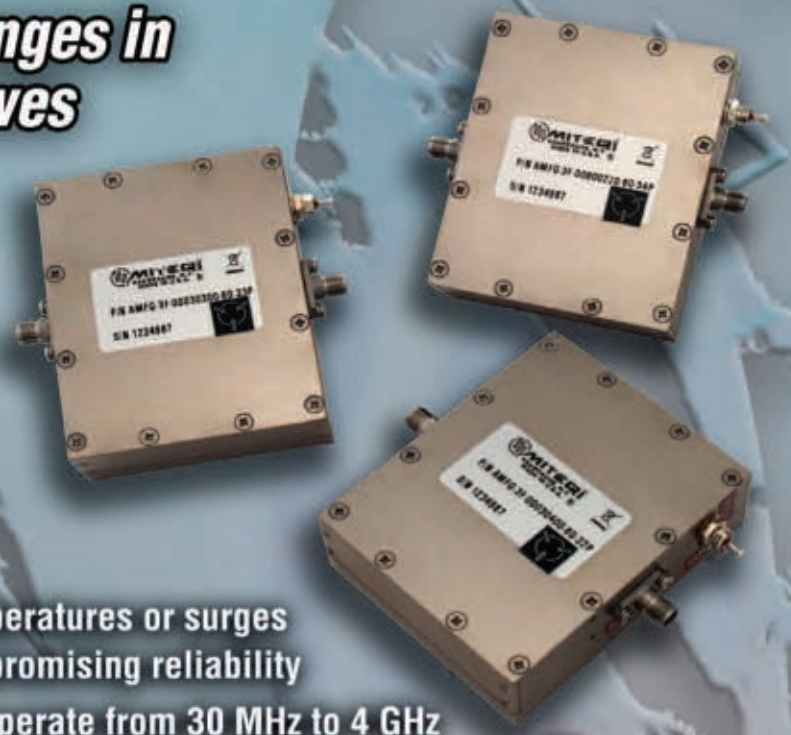

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MODEL NUMBER	FREQUENCY RANGE (GHz)	GAIN (dB, Min.)	GAIN FLATNESS (±dB, Max.)	NOISE FIGURE (dB, Max.)	VSWR IN/OUT	P1dB (dBm, Min.)	Psat (dBm, Min.)	NOMINAL PEAK CURRENT @ 30V (mA)
AMFG-3F-00030100-60-33P	0.03-1	42	1.5	6	2:2	34	36	750*
AMFG-3F-00030300-60-33P	0.03-3	40	2	6	2:2.2	33	35.5	750*
AMFG-3F-00030400-60-32P	0.03-4	40	2	6	2:2	32	35	750*
AMFG-3F-00040250-60-33P	0.04-2.5	40	2	6	2:2.2	33	35.5	670
AMFG-3F-00050100-50-34P	0.5-1	40	1.5	5	1.8:1.8	34	37	750*
AMFG-3F-00230025-30-37P	0.23-0.25	50	1	3	1.5:2	37	40	250*
AMFG-3F-00500350-60-32P	0.5-0.35	40	1.75	6	2:2.2	33	35	600*
AMFG-3F-00700380-60-35P	0.7-3.8	40	2	6	2.5:2.5	35	39	1500
AMFG-3F-00800220-60-35P	0.8-2.2	40	1.5	6	2:2	35	38	900*
AMFG-2F-01000300-60-35P	1-3	40	2	6	2:2.2	35	39	1500
AMFG-2F-01000200-60-38P	1-2	35	2	6	2:2	36	37	1500

Notes: Psat is defined as the output power where a minimum of 3 dB gain compression takes place.
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* 12V version available.

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Model	Type	Frequency (MHz)	Power (WCW)	Size (Inches)	Insertion Loss (dB)	VSWR	Isolation (dB)
D6233	2-Way	10-1000	25	3.25 x 2 x 1.1	0.75	1.35:1	20
D8632	2-Way	20-1000	50	2.2 x 2.02 x 1.5	0.7	1.40:1	20
D8300	2-Way	20-1000	100	2.45 x 2 x 0.91	0.5	1.35:1	20
D8544W*	2-Way	20-1000	100	2.85 x 2.5 x 1	0.5	1.35:1	18
D8682	2-Way	20-1000	500	5.2 x 2.65 x 1.8	0.6	1.35:1	15
D8851W*	2-Way	20-1000	500	5.6 x 3.05 x 1.8	0.6	1.35:1	15
D7365	4-Way	20-1000	100	5 x 2 x 1	0.75	1.35:1	20
D7439	4-Way	20-1000	250	5 x 5 x 1.5	0.75	1.35:1	18
D8746	4-Way	20-1000	500	7.2 x 3.5 x 1.4	0.7	1.35:1	15
D9048	4-Way	20-1000	500	5 x 4.7 x 1.4	0.6	1.35:1	17

* "W" references a Watertight Design

Dual Directional Couplers

Model	Coupling (dB)	Frequency (MHz)	Power (WCW)	Size (Inches)	Insertion Loss (dB)	VSWR	Directivity (dB)
C8858	40	10-1000	250	2.09 x 1.16 x 0.57	0.4	1.30:1	20
C8631*	40	20-1000	150	1.5 x 0.95 x 0.5	0.35	1.25:1	20
C8696	40	20-1000	150	1.76 x 1.16 x 0.57	0.35	1.25:1	20
C8686	40	20-1000	500	5.2 x 2.7 x 1.7	0.35	1.25:1	20

* Non-Connectorized / Tabs

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