Vol. 52 • No. 10

October 2009

Microwave Journal

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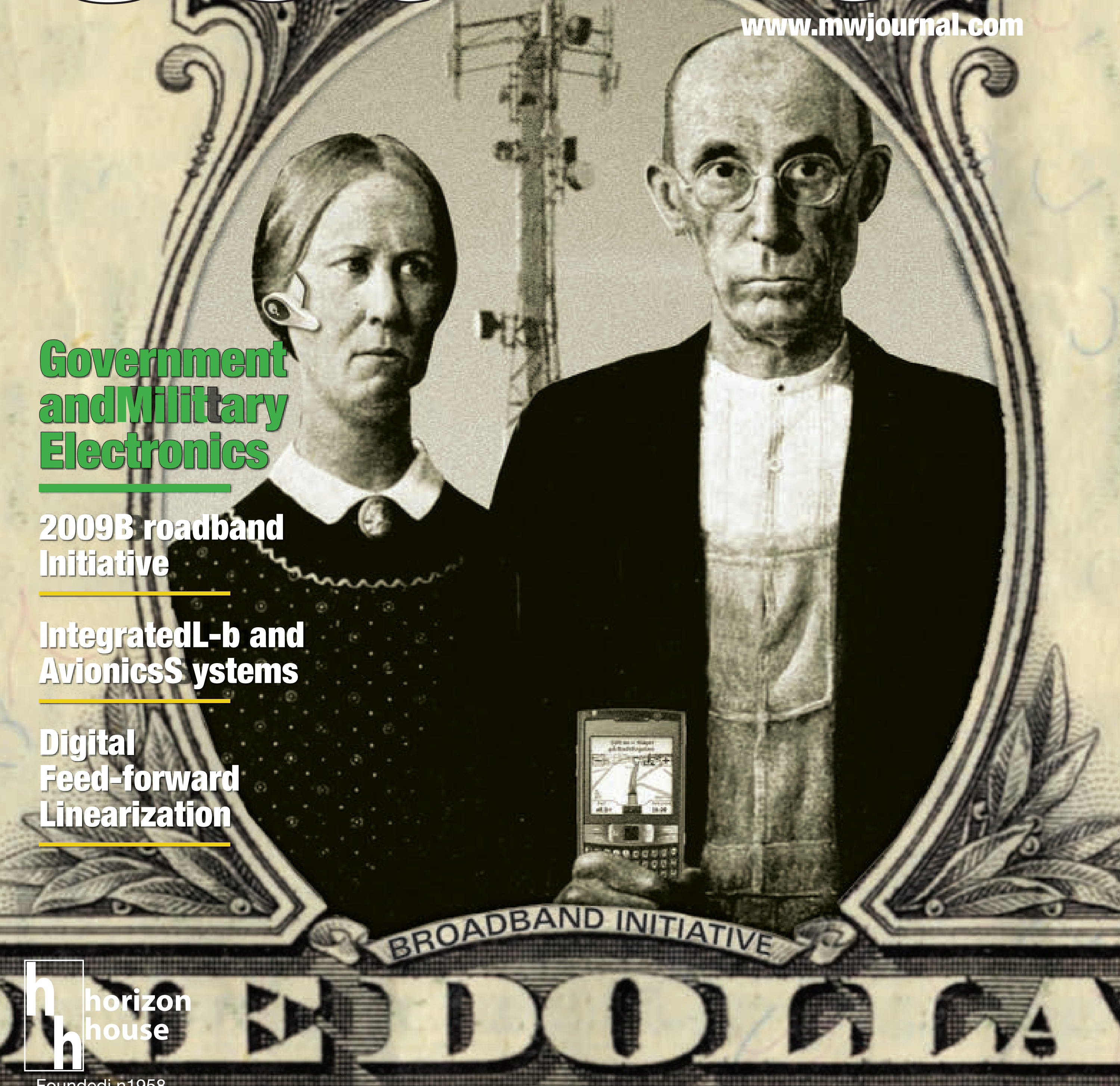

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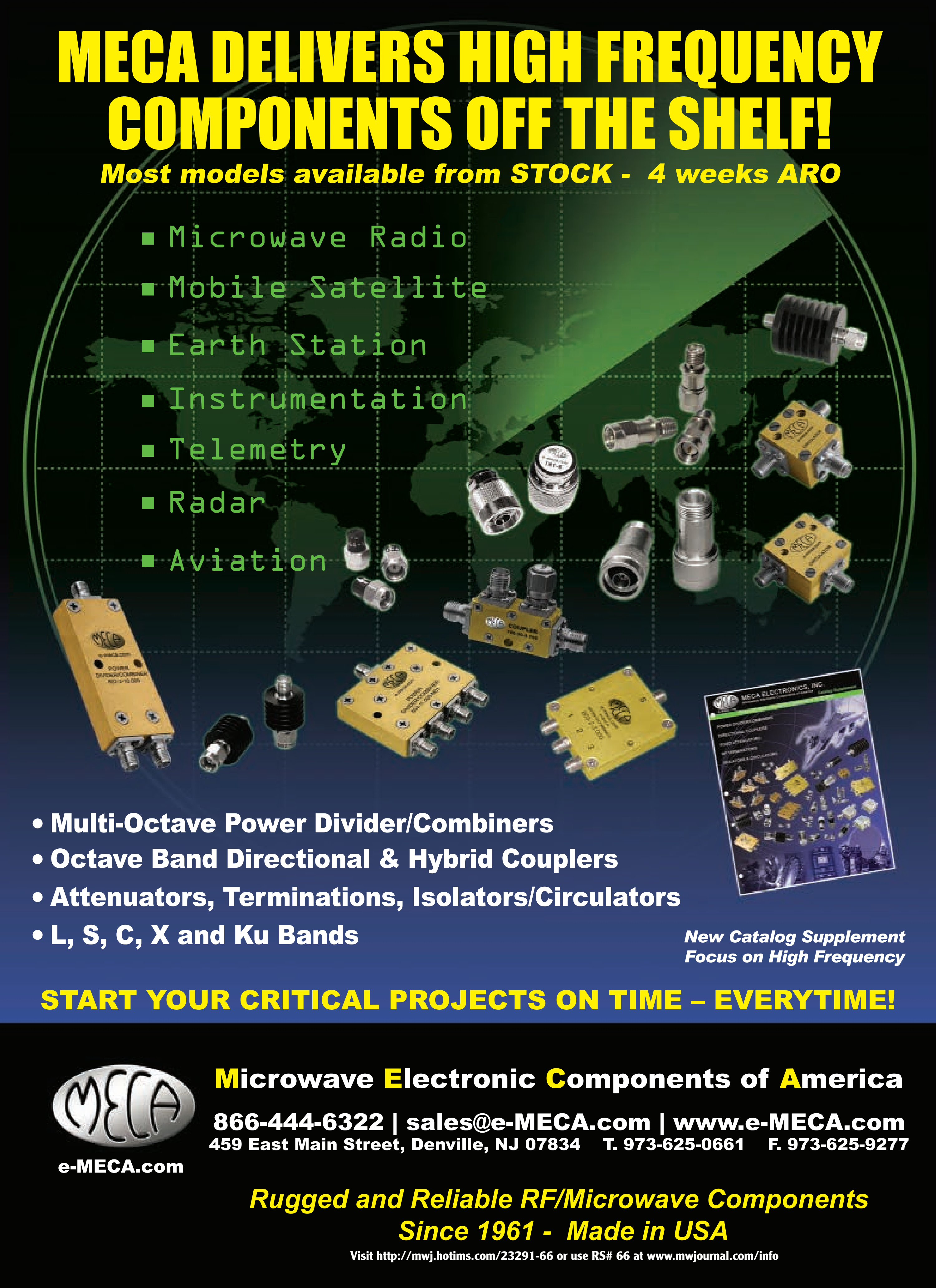
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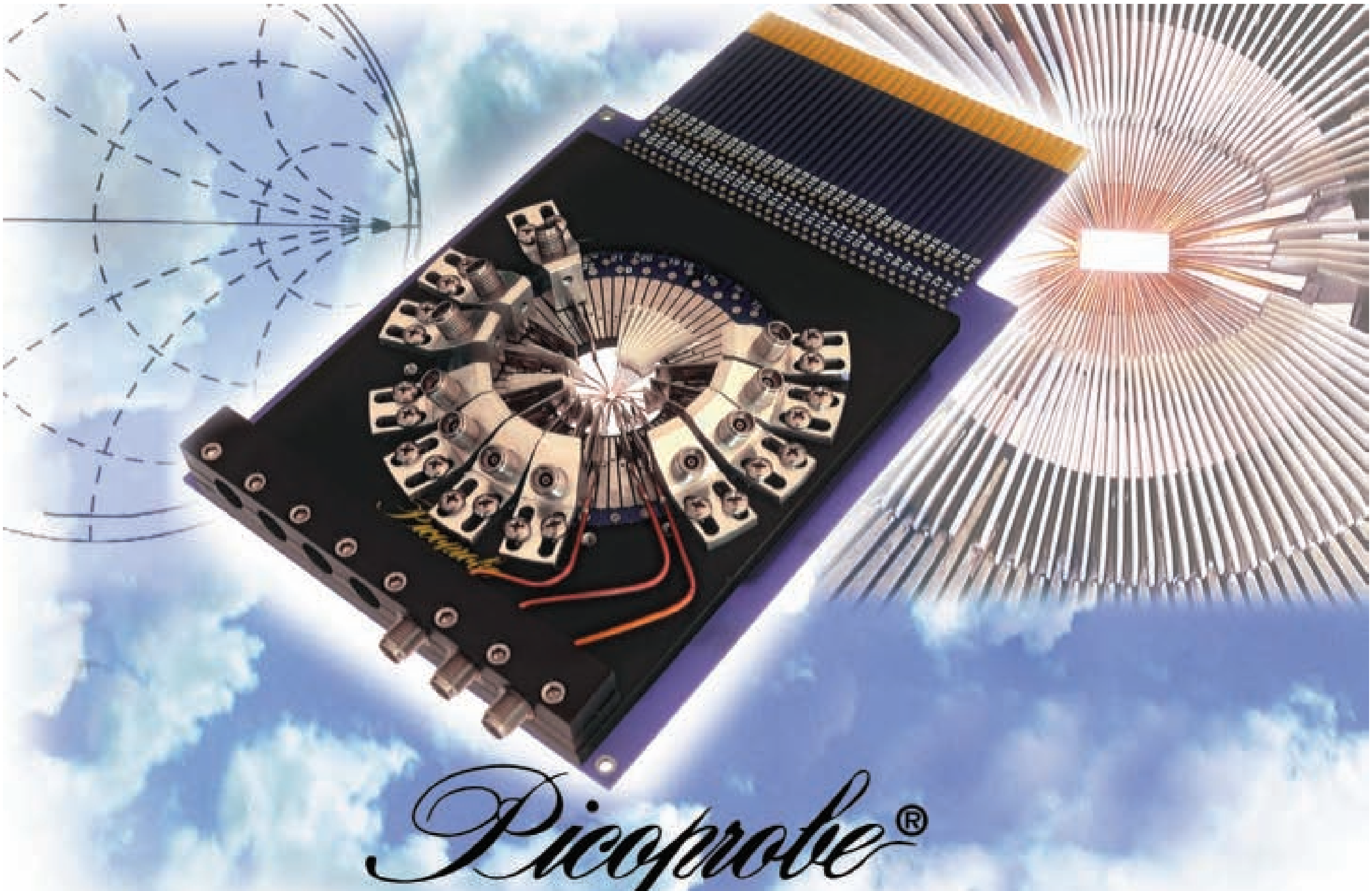

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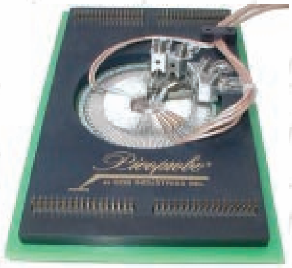

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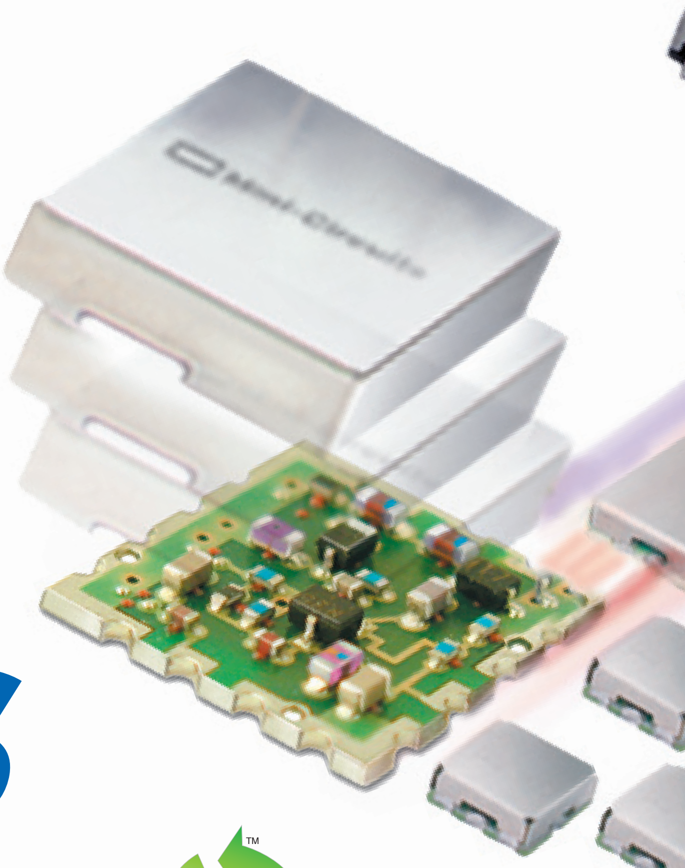

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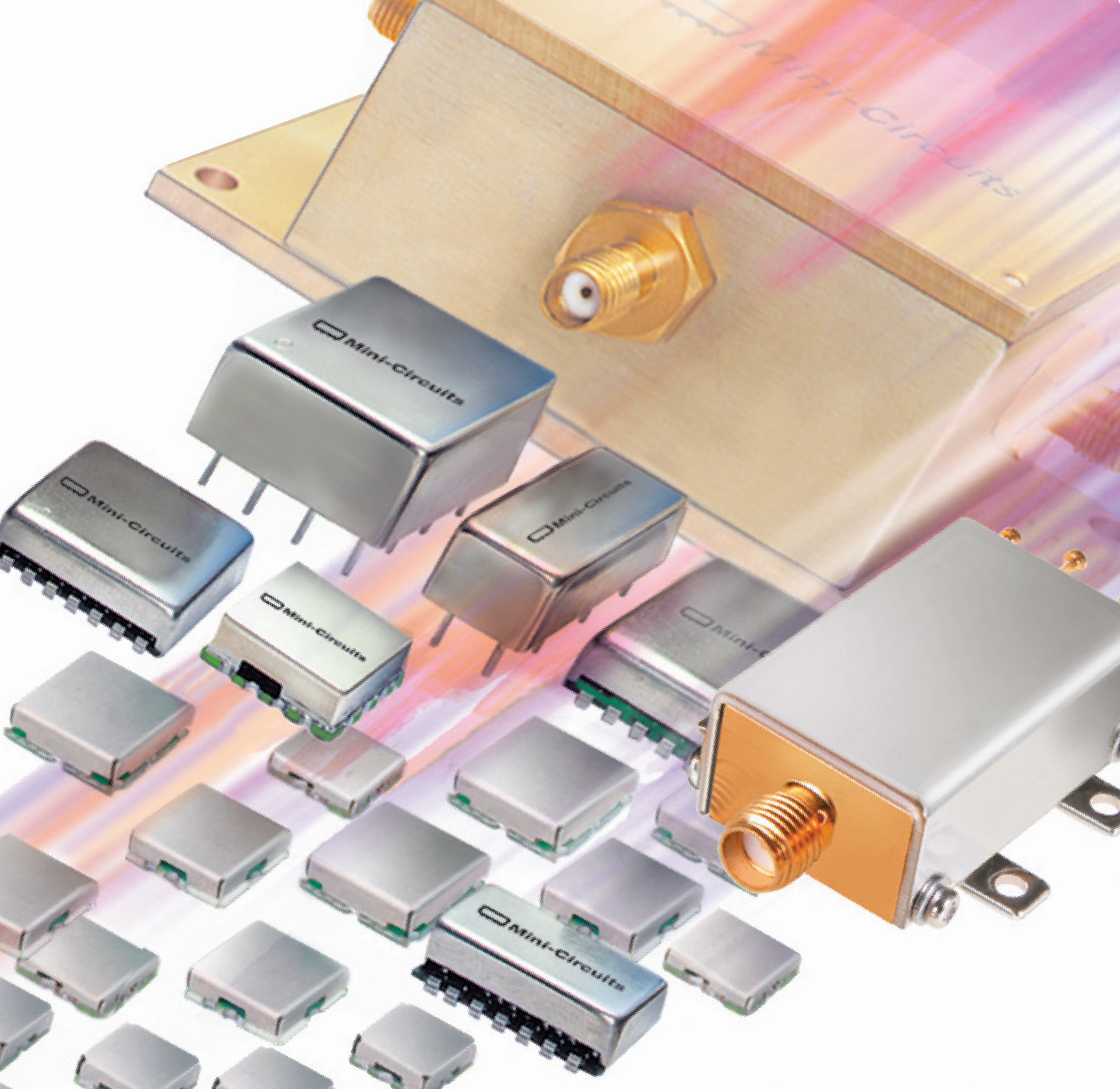
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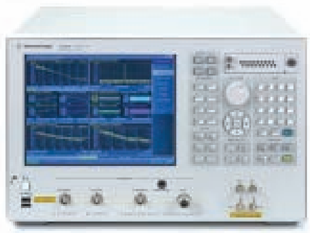

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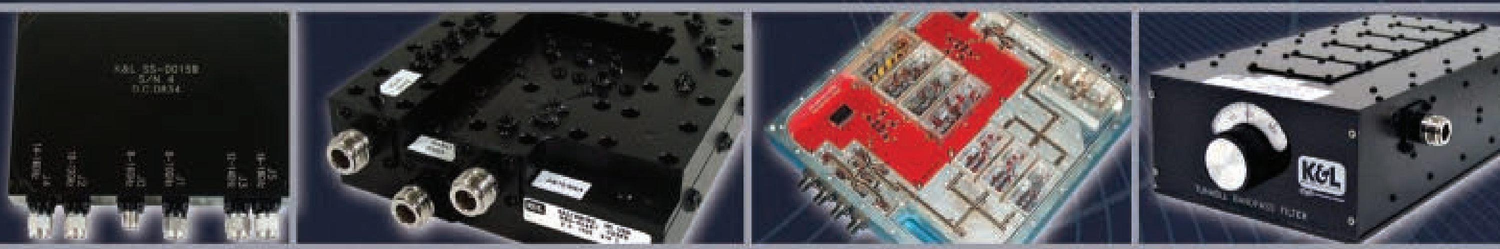

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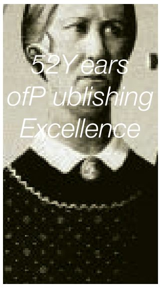
FEATURES

This month's cover image is based on *American Gothic* by Grant Wood



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FEATURES

PRODUCT FEATURES

DEPARTMENTS

In "How Design Software Changed the World," our July Cover Feature, references 2 and 3 were inadvertently listed as one reference. Reference 3 refers to information found at www.microwaves101.com.

I was very interested in your article in the September '09 issue of MWJ called "A Needle in a Haystack: Optimizing Mixer Selection..." I read through the design tradeoffs mentioned in the article about IP3 and LO drive level and so forth, but I noticed that there were parameters left out of that tradeoff analysis that can come into play in most converter designs especially if one varies the LO drive level. Those parameters are the isolation parameters (LO-RF, LO-IF, RF-IF). So while one may be meeting their IP goals with a lower LO drive in this scenario presented, would it affect these isolation specifications? And would those affects be adverse to a person's design? Maybe this article was more about the usefulness of being able to have extra data to aid users, but I do think this one aspect of converter design was omitted and may in this instance cause the design to have more stringent filtering, which could increase loss and require more gain to overcome, thus requiring more power, which would hurt that major design goal as shown in the article. Just a note to those who may read that article and miss that point and go off thinking, "Wow, I got something that solves my problem," only to find that it possibly introduces a new problem.

Michael Ferrara, Honeywell

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White Paper, Spirent

The Class M™ Linearization System and Its Application
David E. Kelly and Kelly Mekechuk, PWRF Inc.

Wireless and Stimulus: A Perfect Match
White Paper, Harris Stratex Networks

Reconfigurable and Cost-effective FET Mixer
Ulrich L. Rohde and Ajay K. Poddar, Synergy Microwave Corp.

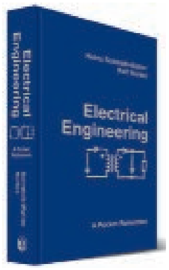
Executive Interview

Microwave Journal talks with **Jim Carroll**, Director of Marketing for **Rogers Corp.**, Advanced Circuit Materials Division in Chandler, AZ. Carroll discusses the company's 175-year history and how they evolved into a leading specialty materials company through a commitment to innovation.

Expert Advice

Andy Singer, President of **Radio Waves**, began his career as an antenna design engineer and has received multiple patents in regards to remote tilt antenna systems. This month, we tap into his expertise on optimizing 4 and 5 GHz antenna systems.

Read the advice from this industry expert, respond with your comments and win a complimentary copy of *Electrical Engineering: A Pocket Reference* from Artech House (see www.mwjournal.com for details).



Show Wrap-ups

There are several trade shows in October. Our editors will be attending **MILCOM** – Boston, MA, October 27, and **AOC** – Washington, DC, October 27. Look for our show wrap-ups at www.mwjournal.com/events.

NOVEMBER 2009

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
1	2 **AMTA 2009 Antenna Measurements Technique Association** Salt Lake City, UT	3	4	5	6	7
8	9 **COMCAS 2009 The International IEEE Conference on Microwaves, Communications, Antennas and Electronic Systems** Tel Aviv, Israel	10	11	12	13	14
15 **MMS 2009 Mediterranean Microwave Symposium 2009** Tangiers, Morocco	16 **LAPC 2009 Loughborough Antennas and Propagation Conference** Loughborough, UK	17 **TriQuint Foundry Webinar** TriQuint SEMICONDUCTOR	18 **IME/China 2009 The 4th China International Conference and Exhibition on Microwave** Shanghai, China	19	20	21
22	23 **ARMMS RF and Microwave Conference** Corby, Northamptonshire, UK	24 **MWJ/Besser: RF Systems Sponsored by:** AWR	25 **MWE 2009 Microwave Workshops and Exhibition** Pacifico Yokohama, Japan	26	27	28
29	30	1	2	3	4	5

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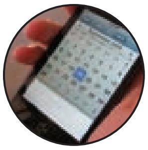

Coming Events

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IEEE Wireless and Microwave Technology Conference
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ONLINE

MILCOM Show Wrap-up
Post date: October 27, 2009
AOC Show Wrap-up
Post date: October 27, 2009
AMTA Show Wrap-up
Post date: November 10, 2009

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OCTOBER

RF & Hyper 2009
October 6–8, 2009 • Paris, France
www.rfhyper.com

International Radar Conference
October 12–16, 2009 • Bordeaux, France
www.radar09.org

MILCOM 2009
Military Communications
October 18–21, 2009 • Boston, MA
www.milcom.org

AOC 2009
46th Annual AOC International Symposium and Convention
October 18–22, 2009 • Washington, DC
www.crows.org

ISAP 2009
International Symposium on Antennas and Propagation
October 20–23, 2009 • Bangkok, Thailand
www.isap09.org

NOVEMBER

AMTA 2009
Antenna Measurement Techniques Association
November 1–6, 2009 • Salt Lake City, UT
www.amta.org

COMCAS 2009
The International IEEE Conference on Microwaves, Communications, Antennas and Electronic Systems
November 9–11, 2009 • Tel Aviv, Israel
www.comcas.org

Mediterranean Microwave Symposium
November 15–17, 2009 • Tangiers, Morocco
www.ieee.ma/MMS2009/

IME/China 2009
November 18–20, 2009 • Shanghai, China
www.imwexpo.com

DECEMBER

74th ARFTG Microwave Measurement Symposium
December 1–4, 2009 • Boulder, CO
www.arftg.org

APMC 2009
Asia-Pacific Microwave Conference
December 7–10, 2009 • Singapore
www.apmc2009.org

RFIT 2009
IEEE Radio Frequency Integration Technology Symposium
December 9–11, 2009 • Singapore
www.ieee-rfit.org

AEMC 2009
IEEE Applied Electromagnetics Conference
December 14–16, 2009 • Kolkata, India
www.ieee-aemc.org

JANUARY

IEEE Radio Wireless Week 2010
January 10–14, 2010 • New Orleans, LA
www.radiowirelessweek.org

MEMS 2010
IEEE International Conference on Micro Electromechanical Systems
January 24–28, 2010 • Hong Kong, China
www.ieeemems.org

FEBRUARY

ISSCC 2010
IEEE International Solid-state Circuits Conference
February 7–11, 2010 • San Francisco, CA
www.isscc.org

NATE 2010
National Association of Tower Erectors
February 15–18, 2010 • Orlando, FL
www.natehome.com

GSMA Mobile World Congress
February 15–18, 2010 • Barcelona, Spain
www.mobileworldcongress.com

MARCH

International CTIA WIRELESS 2010

SATELLITE 2010
March 15–18, 2010 • Washington, DC
www.satellite2010.com

CTIA with RF/Microwave and M2M Zones
March 23–25, 2010 • Las Vegas, NV
www.ctiawireless.com

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MA4P7002F-1072T	200	0.8	0.7	15
MA4PH236-1072T	200	3	0.5	25
MA4P7104F-1072T	400	0.5	1	20
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COVER FEATURE

THE BROADBAND INITIATIVE OF 2009

WILL THE BROADBAND INITIATIVE IMPACT YOUR BUSINESS? WHICH MICROWAVE SOLUTIONS WILL BE MOST COST-EFFECTIVE? IS THE MICROWAVE INDUSTRY WELL REPRESENTED BEFORE GOVERNMENT DECISION MAKERS? WHAT ARE YOUR THOUGHTS? JOIN FURTHER DISCUSSION OF THIS TOPIC AT THE RF AND MICROWAVE COMMUNITY ON LINKEDIN AT WWW.MWJOURNAL.COM/BIP2009.

On February 17, 2009, President Obama signed the American Recovery and Reinvestment Act (ARRA) into law, allocating $7.2 B in grant and loan funding to expand broadband/wireless access to rural unserved and underserved parts of the country. The Department of Agriculture, Rural Utilities Service (RUS) and the Department of Commerce, National Telecommunications and Information Administration (NTIA) will distribute the funds to competitively chosen awardees. This special report takes a look at this Broadband Initiative Program, the potential impact on the microwave industry and the US economy as a whole.

THE ECONOMIC IMPACT OF BROADBAND

In July 2007, the Brookings Institution released a report on economic policy entitled, "The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of US Data,"[1] detailing how high-speed Internet access and the underlying infrastructure have become essential to the global information economy. At the start of the decade, there were only four million broadband lines in the US allowing one house in 30 to download at speeds of 200 kbps or greater. Six years later that number soared to more than 53.5 million (49 million residential). An April 2009 study conducted by the Pew Research Center's Internet & American Life Project found that 63 percent of adult Americans have broadband at home, up 15 percent from a year earlier.[2]

Correlating broadband access to economic growth, the report notes that "for every one percent increase in broadband penetration in a state, employment is projected to increase by 0.2 to 0.3 percent per year. For the entire US private non-farm economy, this suggests an increase of about 300,000 jobs." Information Computing Technology (ICT) contributed 59 percent to labor productivity from 1995 to 2000 and 33 percent from 2000 to 2005. A sample of 21 free-market (OECD) countries between 1970 and 1990 found that about one-third of the per capita GDP growth (0.59 to 1.96 percent per year growth rate) could be attributable to telecommunications infrastructure investment. At the start of this decade, over 2,000 US firms across the economy confirmed that Internet business solutions added a net gain of almost $600 B and are expected to add a total of 0.43 percentage points to US

DAVID VYE
Editor, Microwave Journal

productivity growth through 2011.

In January, the Washington, DC-based Information Technology and Innovation Foundation (ITIF) released a report entitled, "The Digital Road to Recovery: A Stimulus Plan to Create Jobs, Boost Productivity and Revitalize America," estimating that an investment of $30 B in America's IT network infrastructure in 2009 will create approximately 949,000 US jobs. Specific to broadband networks, the report estimates that a stimulus package supporting $10 B of investment in one year will result in an estimated 498,000 new or retained US jobs for a year.[3]

US GLOBAL BROADBAND RANKING

Several studies have looked at broadband access from the perspective of global competition. According to a report by Strategy Analytics, 60 percent of US households accessed the Internet via broadband in 2008, compared to 95 percent in South Korea (see ***Table 1***). The US ranked 20th and will likely drop to 23rd place worldwide by next year. The median US download speed currently is 1.97 megabits per second compared to the 61 megabits per second in Japan, South Korea (median 45 megabits), France (17 megabits) and Canada (7 megabits).[4]

Internet speed has a direct impact on productivity. A 10 megabyte file takes about 15 seconds to download with a 5 Mbps connection (over twice the US median speed). Download time is almost 2½ minutes with the entry-level 545 kbs connection speed found in many areas in the US. Superfast speeds supporting critical applications such as telemedicine are directly tied to network capacity, which relates back to infrastructure and the microwave industry via wireless access and backhaul.

Currently, the Federal Communications Commission (FCC) defines "high speed" as 200 Kbps, a benchmark adopted more than a dozen years ago when dial-up service was the rule. At the moment, RUS and NTIA are favoring the current threshold because "it leverages the FCC's expertise, utilizes an established standard, facilitates the use of many currently common broadband applications (e.g., web browsing, VoIP, and one-way video), allows for consideration of cost-effective solutions for difficult-to-serve areas and is the most technology-neutral option (because it encompasses all major wired and wireless technologies)."[5]

This past April, the FCC opened proceedings that could redefine broadband access speeds and plans to study the competitive nature of the US wireless industry and how to "encourage further innovation and investment." By August, US telecommunications regulators announced they were seeking public comment on how to define "broadband" as it drafts a national broadband plan that is slated to be submitted to Congress in mid-February.

In March, the New America Foundation (NAF) recommended several policy proposals to encourage greater rural deployment. The NAF encouraged greater wireless deployment through increased access to spectrum, doing so through the thousands of "locally-grown" wireless ISPs (WISP). Recent spectrum occupancy studies by the Shared Spectrum Co. and funded by the National Science Foundation exposed large swaths of vacant spectrum especially in rural areas. For this reason, the NAF recommended a hybrid approach for rural access, utilizing different technologies and resources to tap under-utilized spectrum. The foundation also recommended mapping public spectrum capability for a more complete and transparent accounting of available frequency-by-location data.[6]

Another major proposal calls for increased access to high-speed Open Access and wholesale middle-mile infrastructure. The middle mile is defined as broadband infrastructure that does not predominantly provide service to an end user, but which includes interoffice transport, backhaul, Internet connectivity or special access. Connecting last-mile networks (service to end-users) to the Internet backbone is a major obstacle for operators. The typical rural ISP is 91 miles from its primary backbone connection. The NAF's proposal advocated installing "dark fiber" or excess capacity in conjunction with all new road construction and repair.

TABLE I

STRATEGY ANALYTICS: GLOBAL HOUSEHOLD BROADBAND PENETRATION RANKINGS (2008)

Rank	Country	HH Pen
1	South Korea	95%
2	Singapore	88%
3	Netherlands	85%
4	Denmark	82%
5	Taiwan	81%
6	Hong Kong	81%
7	Israel	77%
8	Switzerland	76%
9	Canada	76%
10	Norway	75%
11	Australia	72%
12	Finland	69%
13	France	68%
14	United Kingdom	67%
15	United Arab Emirates	65%
16	Japan	64%
17	Sweden	63%
18	Estonia	62%
18	Belgium	62%
20	United States of America	60%
21	Slovenia	58%
22	Germany	58%
23	Ireland	58%
24	Spain	57%
25	New Zealand	57%

Meanwhile, Harris Stratex advocates a wireless solution to the backhaul problem, stating that the transmission cost per bit is approximately 40 to 50 percent lower than the cost of fiber (according to ABI Research). According to a Harris Stratex white paper, the deployment cost for fixed wireless (including microwave) link is about $50,000 per 100 Mbps fully installed versus $200,000 to $800,000 per mile for fiber.[7]

BACK-STORY: BRINGING BROADBAND TO THE HEARTLAND

Government investment in infrastructure has a long and successful history of reshaping the nation from the building of the roads, canals and ports, which extended commerce in pre-Civil War America; the transcontinental railroads that transformed

the country into a continental power in the late nineteenth century; to the immense public works program that brought telephone and electrical service to rural America during and since the Great Depression. In the 1950s, the federal government funded the ambitious highway construction program, opening up remote areas to more residents. As sprawl and technology advanced, many missed out on the services and opportunities that came with the emergence of IT over the past 30 years. Currently, only 38 percent of Americans living in rural areas subscribe to broadband, compared to 57 percent in urban and 60 percent in suburban areas.[8]

The FCC defined the unserved and underserved in a recently released report. As of 2008, 83 percent of US citizens had access to DSL, and 96 percent had access to cable modems. The number of high speed lines increased by more than 11.5 million lines, approximately 10 percent, during the first six months of 2008 to more than 132 million lines. Assuming the economy slowed this growth rate over the last year, the number could still be nearing 145 million lines. This means that only 1 or 2 percent of US subscribers are now without the ability to get basic broadband. The report goes on to reveal 68 percent of the US population have broadband access with rates 2.5 Mbps or greater, with 8 percent having access greater than 10 Mbps. This implies that the underserved segment of the market is significantly more in need of stimulus infrastructure spending. The report concludes that the stimulus Broadband Initiative Program (BIP) should be spent on broadband infrastructure that will last for 10 years or more, supporting the argument for aggressive bandwidth targets.[9]

The USDA Rural Development Agency got involved with broadband back in 2000 with a $100 M pilot loan program (an extra $80 M was provided by the Agriculture Appropriations Act of 2002). The initial program delivered 28 loans totaling $180 M in 20 states and established what the needs and interests were for broadband in rural America.

By 2007, the program had approved loans in 40 states, serving 1,263 communities (582,000 household subscribers) totaling over $1.22 B of investment. According to the agency, this program established broadband access as a transformative technology that allowed rural communities to drastically enhance the quality of their health care, education and economic opportunities. Forty percent of the early projects were successfully completed, while 30 percent of the loans defaulted, resulting in changes to the risk-mitigating rules applied to subsequent loan programs including the current loan/grant application process.[10]

RUS's BIP intends to create thousands of jobs while providing the benefits identified during earlier programs. The recovery act requires that 75 percent of a BIP-funded area "lacks sufficient access to high-speed service to facilitate rural economic development." Regulatory policies must promote technological neutrality,

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competition, investment and innovation to ensure that broadband service providers have sufficient incentive to develop and offer such products and services. These technologies include fiber to the home, wireless, satellite, broadband over power lines and hybrid fiber/coax systems.

RURAL NEEDS AND CHALLENGES

One of the fundamental decisions behind a cost-effective rural communications network is the choice of physical network technology. With relatively rapid deployment speed, low cost and ability to cover large areas with a single base station, wireless is one of the more viable options. For sparsely-populated areas, it is much more cost effective than deploying fiber-to-the-home. In North America, it takes six to nine months to deploy fiber in a location, representing the time required to plan, engineer, order, install and build the fiber according to an ABI Research report on Mobile backhaul – Global market analysis and forecast 2009-2014.[7]

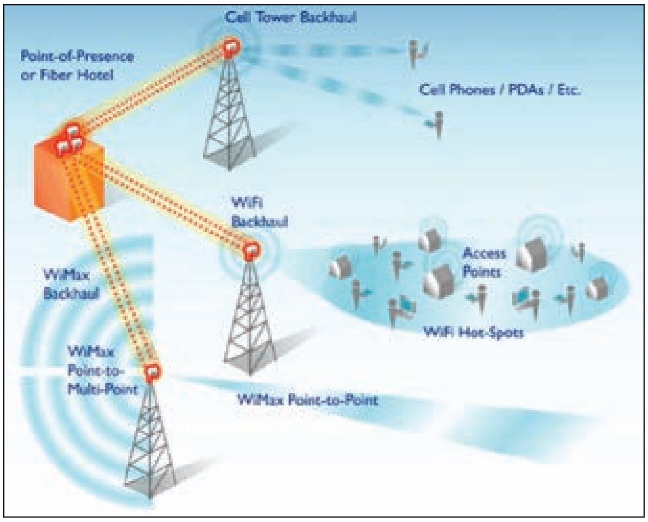
Rural networks serve far fewer customers per square mile and are typically more expensive to deploy and maintain (see ***Figure 1***). While these networks are fundamentally similar to urban networks with local access and a backhaul component, rural broadband networks are geographically farther from Internet backbone nodes. In many cases, the provider will need to obtain backhaul transport, or "middle-mile" facilities, from more than one provider, often over facilities that were designed for voice telephone or cable television services. Currently, some of these "middle-mile" facilities have insufficient capacity, causing the transmission speed on otherwise adequate last-mile broadband facilities to come to a crawl or stall before the data reaches the Internet backbone (see ***Figure 2***).

According to an FCC report on its rural broadband strategy from this past May, overcoming this issue will require the construction of dedicated facilities, driving up costs and deterring last-mile broadband investments. Moreover, even when the last-mile provider acquires access to adequate middle-mile facilities, that access may be prohibitively expensive. It is argued that the stimulus funding is needed to trigger deployments that would not otherwise occur.[11]

There is no one solution to addressing middle mile transport costs in rural areas. Comments to regulators suggest explicitly encouraging middle-mile build-out, revising universal service funding to help cover costs of the middle-mile, and using current or potential infrastructure more effectively by coordinating with other infrastructure projects to shrink deployment costs, and reforming interconnection obligations.

Delivering high capacity services such as WiMAX will require significant backhaul scale. Each site may have requirements growing up to 50 to 100 Mbps per tower. Multiple tower sites may need to be aggregated together across a single link before reaching fiber, which will drive some backhaul capacities up to nearly a gigabit. Greg Friesen, Director of Product Man-

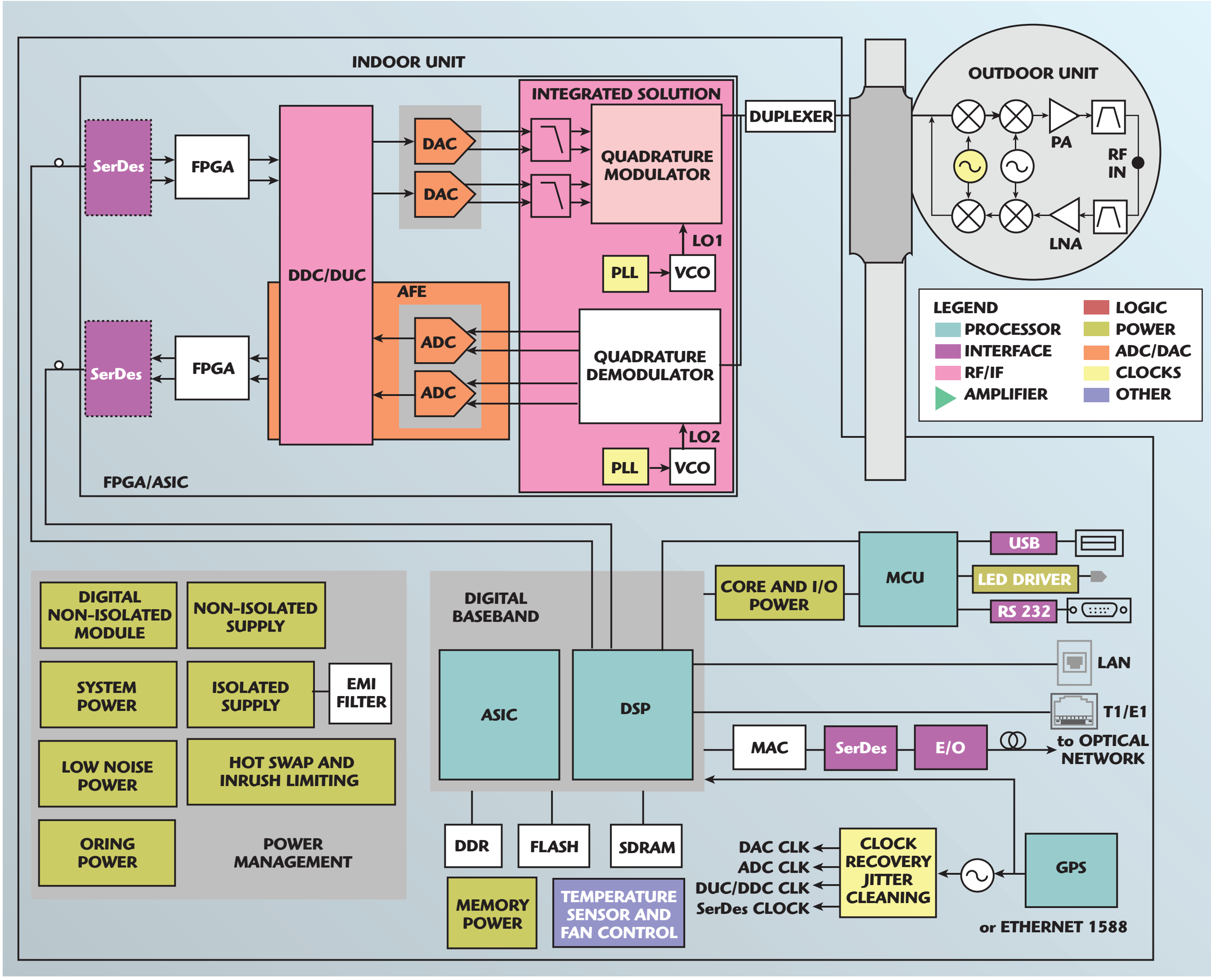
agement for Dragonwave, identified some of the major challenges on the backhaul side of these deployments. Leading concerns include: capacity for future scalability; network reach to rural areas; limited site options for deployment; long repair times, driving redundancy and uncertain economic viability after the initial capital expenditures.[12]



▲ *Fig. 1 Wireless backhaul diagram for cellular/PCS, 3G/4G, WiFi and WiMAX (courtesy of Polimetrix Systems).*

According to Dragonwave, the first backhaul challenge is to deliver the required high Ethernet capacity at each of these sites. Some recently licensed Ethernet microwave systems cannot offer capacities of 400 Mbps up to over a gigabit. These solutions can provide high capacity last-mile transport. They can also serve on aggregation links shared among multiple sites. In addition, some of these radios have capacity scalability via remote software keys. This can enable a lower initial cost without sacrificing future scalability.

The wide range of distances that will be required for these deployments will drive a wide range of frequencies. In rural areas, for long hops, 6 GHz may be required. The downside to this is that there are only 30 MHz channels in this band, limiting the throughput to about 200 Mbps per license. In addition, at 6 GHz there is a minimum antenna size of six feet, making deployment more difficult and expensive, and driving up tower space leasing costs. A good alternative is 11 GHz, which supports an antenna size of 2.5 feet, and 40 MHz channels



▲ *Fig. 2 Block diagram of wireless point-to-point (P2P) microwave backhual system (courtesy of Texas Instruments).*

allows close to 300 Mbps throughput per license, with a much simpler installation, and reduced infrastructure requirements.

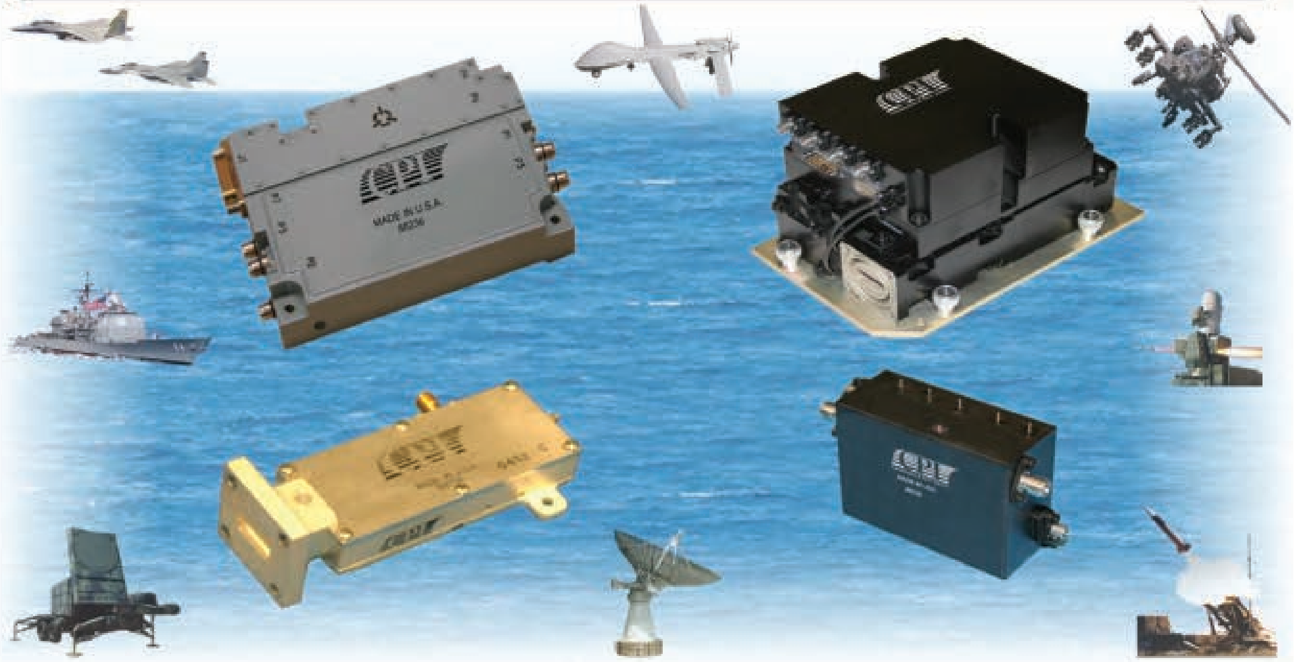
For the shorter hops, where NTIA funding is focused on covering underserved areas, 18, 23 and even higher bands like 28 GHz can be considered. Some of these bands allow one foot antennas and they all have 50 MHz channels, enabling up to 400 Mbps throughput per license. In addition to considering multiple spectrum options, reach can be significantly increased though Adaptive Modulation, which is now available on some licensed microwave systems. Adaptive modulation shifts to a lower capacity and modulation during rain fade (or other environmental effects), maintaining the link but at a reduced capacity. During this event, the link will prioritize the critical traffic, to ensure services such as voice calls are maintained. Adaptive Modulation allows the service provider to engineer the link distance based on modulation.

Another wireless technology that could benefit in the wake of the broadband stimulus package is 802.11y, the 3.65 to 3.70 GHz WiFi standard approved by the IEEE in September 2008. The "lightly licensed" spectrum allows prospective operators to pay a small fee for a nation wide, non-exclusive license and then pay an additional nominal fee for each high powered base station that they deploy. Neither the client devices (which may be fixed or mobile), nor their operators require a license, but these devices must receive an enabling signal from a licensed base station before transmitting. All stations must be identifiable in the event they cause interference to incumbent operators in the band. The higher power level can provide good backhaul in rural areas in the Southwestern and Southern United States and municipal WiFi networks.

Just as satellites provide necessary links for telephone and television, they can also provide links for broadband. Downstream and upstream speeds for satellite broadband depend on several factors, including the provider and service package, the consumer's line of sight to the orbiting satellite and the weather. Typically, a consumer can expect to download at a speed of about 500 Kbps and upload at a speed of about 80 Kbps. These speeds may be slower than DSL and cable modem, but they are about 10 times faster than the download speed with dial-up Internet access.

In testimony to the FCC this past August, Ken Carroll, President and COO of WildBlue Communications, one of the two primary providers of satellite broadband today (along with HNS), discussed the state of broadband satellite and its potential role in provided broadband to the unserved. Satellite broadband is currently serving one million customers. Carroll projects that in five to seven years there will be close to five million satellite broadband consumers, primarily rural, unserved and underserved.

Today, the company's two satellites operate on a first generation platform, combining to generate about 10 gigabits of capacity. The next generation platforms will bring significantly



more capacity and speed. With the next generation, each satellite brings approximately 100 gigabits of capacity, allowing speeds of 10 to 15 megabits and significantly more volume throughput. Also, satellites don't have some of the middle-mile issues that the rest of the wireless industry does. Satellites have gateways and are able to aggregate traffic and usually locate those in competitive fiber market areas in order to get the best pricing on that "middle-mile."[13] On the negative side, satellites require more expensive end-user equipment and have technical issues, such as latency (500-700 ms) and signal loss due to precipitation.

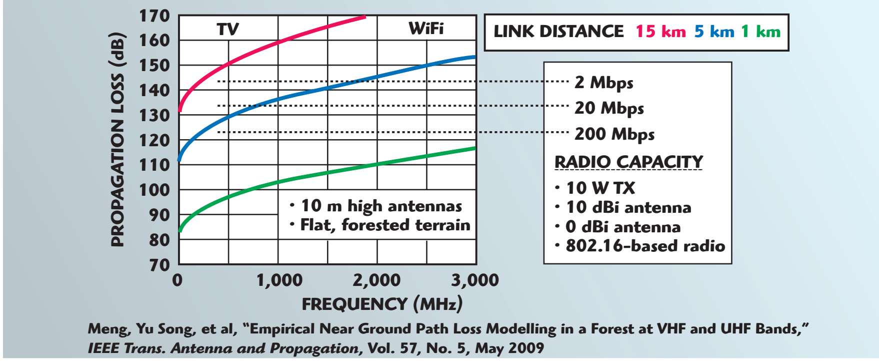
THE COST OF CONNECTING RURAL AMERICA

Long link range is critical to giving wireless an economic advantage. For a base station link range of 1/2 km serving an area of 22811 km^2, 29044 base stations would be required. At a per base station cost of $50,000, the total cost would be $1.4 B or $2,250 per person for a population density similar to that in southwest Virginia. If the link range could be extended to 15 km, the number of required base stations would drop to 32 at a cost of $1.6 M or $2.51 per person.[14]

To help extend the link range, Brett Glass, founder of LARIAT, a non-profit co-op serving unserved/underserved areas, implored the FCC to devote more nonexclusive licensed spectrum to wireless broadband, with mandatory spectrum etiquettes to enable cognitive radio and effective spectrum sharing along with an increase of power limits in rural counties (population <200K) by 9 dB for Part 15 WISPs on 900 MHz, 2.4 GHz, 5.3 to 5.8 GHz, and 60 GHz (for inter-tower links).

Smart radios and autonomous dynamic spectrum utilization was also advocated by Mark McHenry, CTO of Shared Spectrum Co. The reasoning is, while spectrum may be allocated and assigned, most of it is unused, especially in rural areas. The coveted spectrum includes the (VHF/UHF) frequency bands which increase link range and reduce propagation loss by selecting the "best" frequency for building penetration and minimal foliage attenuation, as shown in ***Figure 3***.[15] Cognitive radio, often thought of as a software-defined radio extension (Full Cognitive Radio), is the proposed method to better utilize this spectrum by 10 to 100 percent. Much of the research work is currently focusing on Spectrum Sensing Cognitive Radio, particularly in the TV bands. The essential problem of Spectrum Sensing Cognitive Radio is in designing high quality spectrum sensing devices and algorithms for exchanging spectrum sensing data between nodes.

Gary Kim, a contributing editor with TMCnet, is less than optimistic about the broadband initiative being able to meet its goals. He places the number of unserved broadband locations at around 600,000. At a cost per new location of about $9,000 for construction and equipment, it would take $5.4 B. With $2.5 B to spend, RUS could connect something less



▲ *Fig. 3 Propagation loss vs. frequency and link distance.*

than 278,000 new locations. Beyond that, there might be eight million or so rural locations that already have gotten some RUS support in the past, and which might be upgraded for as little as $500 per location, using wired facilities. That implies additional investment of $4 B. There also might be another one million locations more than 18,000 feet from a central office or repeater and which might be upgraded for broadband, using wired facilities, for about $4,000 a location. That would imply an extra $4 B in investment.[15]

Dave Burstein, editor of the DSL Prime newsletter and panelist on the FCC workshop on the National Broadband plan, is more optimistic and pragmatic with his advice to the regulators. He agrees with Kim that 50 to 70 percent of unserved homes can access megabit speeds for under $400. Thirty to 40 percent (up to four million homes) of these locations get cable TV and could receive data with a cheap upgrade; another 20 to 30 percent would require new towers or DSL repeaters at an average cost of $2500 per home. Total cost would be about $7 B to cover all but one to two percent of the US with megabit speed. As this last group gets into the $10K+ range per home, they may best be served by satellite. Burstein also recommends bringing down backhaul cost by special access (middle-mile investment) and staying away from subsidies for home equipment, routers and switches.[16]

LOOKING AT PAST GOVERNMENT TECH SPENDING

On May 25th, 1961, President Kennedy announced to a joint session of the US Congress that, "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth. No single space project in this period will be more impressive to mankind, or more important in the long-range exploration of space; and none will be so difficult or expensive to accomplish." With the political conflict, military tension, scientific and economic competition of the Cold War escalating, Kennedy decided the country needed to impress mankind (and the communist block countries, in particular) with an unprecedented ac-

complishment of scientific achievement, despite the difficulty or cost. Internal memos in the White House reflected the administration's fear that countries around the world would eventually align themselves with the winner of the space race, regardless of ideology.

At the time of Kennedy's speech, only one American had flown in space (less than a month earlier) and NASA had not yet sent a man into orbit. As the administration was proposing a program that would have a final cost between $20 and $25.4 B in 1969 dollars (or approximately $150 B today), the country was experiencing a brief recession. While some cynics expressed their concern and opposition to this spending, the majority of the country gathered around the effort and supported its successful completion.

Money spent on the space program was ultimately responsible for much of the early development of the integrated circuit, communications, GPS, LandSat and other technical advancements in high-frequency electronics. Much of the world's present day economy is based on the technologies derived from this government investment. The impact on people was equally impressive as a whole generation of Americans pursued an education in math, science and engineering. Government spending is often controversial (especially during a recession), yet the favorable long-term economic impact of this current broadband program seems undeniable. The big unknown is whether the complexity of serving a diverse and sparsely located population with a myriad of technologies can be done in such a way that both tax payers and government watchdogs feel good about the long-term return on investment. ■

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"We have been using this coupler for our UHF, High Power testing since we opened in 1974."

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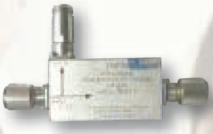
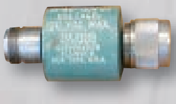


Technical Consultant
Wayne Miller Associates, LLC

"Part in service before 1982."



Engineer
INAF - IRA

"These Narda coaxial load and tuning stubs have been in service since the 1970s."

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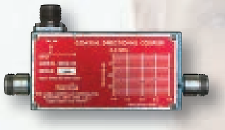
Aptec Electronics

"Model 3003-30, S/N 654. In service for 25 years, and still going strong."



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"Equipment has been in use at our RF lab since 1990. Your stuff is reliable, robust and accurate, we do not want to do without it."

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"769-30 30dB 150W attenuator. One of its properties I really like is that it is bidirectional, no high power "input" or "output". That feature ensures you can't go wrong with this attenuator!"

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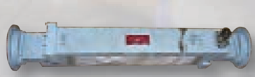
"Forward/reverse coupler placed into service in the mid to late 60s in a series of government radars."



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Designer
Petrini Electronics
"My oldest Narda is a Microline directional coupler...in service since 1982. Thanks for the very good quality of this important equipment over several years."
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Frank Koeditz Nachrichtentechnik
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Harris Radio Simplifies Interoperable Tactical Communications

Harris Corp., an international communications and information technology company, announced it has received certification from the National Security Agency (NSA) for the Harris RF-310M-HH, the world's first tactical radio to utilize new encryption technology designed to simplify the enabling of communications interoperability within multinational coalitions. Harris and NSA collaborated on the new technology, which is based on a set of commercial algorithms and keying techniques defined as "Suite B."

The Harris RF-310M-HH is a multiband, multi-mission, software-defined Suite B radio certified to transmit voice and data up to the US SECRET level. The objective of the Harris/NSA joint project is to make it easier for US forces and coalition partners to communicate on the battlefield, resulting in improved coordination, easier mission planning and reduced instances of friendly fire. These radios will be commercially available to coalition partners with limited restrictions and will enable secure communications with US troops using other equipment such as the JTRS-approved Falcon III® AN/PRC-152(C) handheld and AN/PRC-117G manpack radios.

The RF-310M-HH radio offers an easy-to-use, cost-effective way of transforming the ad-hoc nature of communications among coalition partners in conflicts such as the war in Afghanistan. This new radio will enable nations in the International Security Assistance Force to modernize and securely interoperate throughout the coalition.

The RF-310M-HH radio, covering the 30 to 512 MHz frequency range, leverages the expertise of Harris Corp. as the leading provider of software-defined tactical radios around the world. The RF-310M-HH is interoperable with the JTRS-approved AN/PRC-152(C) handheld and AN/PRC-117G manpack radios. There are more than 80,000 AN/PRC-152(C) radios deployed around the world.

The RF-310M-HH radio is based on the Advanced Encryption Standard (AES) and uses the Sierra 2B Core Software, recently certified by the NSA. The radio also includes the Type-3 APCO P25 waveform, enabling interoperability with public safety first responders. Because the RF-310M-HH is a software-defined radio built and compliant with the Software Communications Architecture (SCA), the radio is positioned to host other current and future waveforms.

SRCTec Wins US Army Contract

The US Army Communications-Electronics Life Cycle Management Command has awarded SRCTec a five-year Indefinite Delivery/Indefinite Quantity contract with an approximate value of $700 M for Counter Remote Control Improvised Explosive Devices (RCIED) Electronic Warfare (CREW) Duke V2 system upgrades. The CREW Duke counters radio-controlled roadside bombs, or IEDs, and is currently the US Army's most widely fielded CREW system. The initial order is for $188 M. SRCTec anticipates that this award will result in the addition of up to 50 production positions in 2010.

SRCTec has been providing the US Army and other military services with counter-IED solutions since its inception in 2006, and their products have played a critical role in reducing the number of IEDs detonated in the field. The system's first generation Counter-Measure Protection System was one of the US Army's Top 10 Inventions in 2005.

Mary Ann Tyszko, President and Chief Executive Officer of SRCTec, stated, "Providing products that save lives and bring our soldiers home safely is our first priority. This award allows us to continue our mission to protect the warfighter against IED threats in the global war on terror."

Raytheon Signs $151 M Evolved SeaSparrow Missile Contract

Raytheon Co. was awarded a $151 M contract by the US Navy's NATO SeaSparrow program office to produce 186 Evolved SeaSparrow Missiles, with an option for $210.3 M to produce an additional 255 missiles. The agreement will also provide NSPO consortium member navies with spare parts and missile containers.

Deployed in the US Navy and nine international fleets, ESSM defends the battlespace by delivering ship self-defense firepower against high-G maneuvering anti-ship cruise missiles as well as surface and low-velocity air threats.

"Raytheon, along with our international team of 18 partner companies, has advanced this world-class system to a point of prominence in ship self-defense missiles," said Ed Roesly, Raytheon's ESSM Program Director. "This contract cements the ESSM's future, and next year will be exciting as we expand our worldwide customer base."

As a tail-controlled missile, ESSM uses recent enhancements to its guidance system to take advantage of improved seeker sensitivity, increased propulsion and greater weapon accuracy. These features enable ESSM to arrive at the intercept point with more endgame speed and agility to counter the threat.

Herley Awarded $16.6 M IDIQ Contract

Herley Industries Inc. announced that through a subsidiary, it has been awarded a $16.6 M firm-fixed-price, time and material, indefinite-delivery/indefinite-quantity (IDIQ) contract for Radio Frequency (RF) Modules. As required, repair services and engineering and technical support services will also be performed. The Naval Air Warfare Center Weapons Division, China Lake, CA, is the contracting activity.

Richard F. Poirier, CEO and President, commented, “The RF Modules under this multi-year IDIQ contract are very complex integrated microwave assemblies used in airborne threat simulators. This five-year IDIQ contract is a follow-on award to a previous IDIQ contract for the same modules. We are very pleased to continue to provide Herley technology, engineering and quality products in support of the US Government.”

Rockwell Collins Avionics Selected for EgyptAir A330s

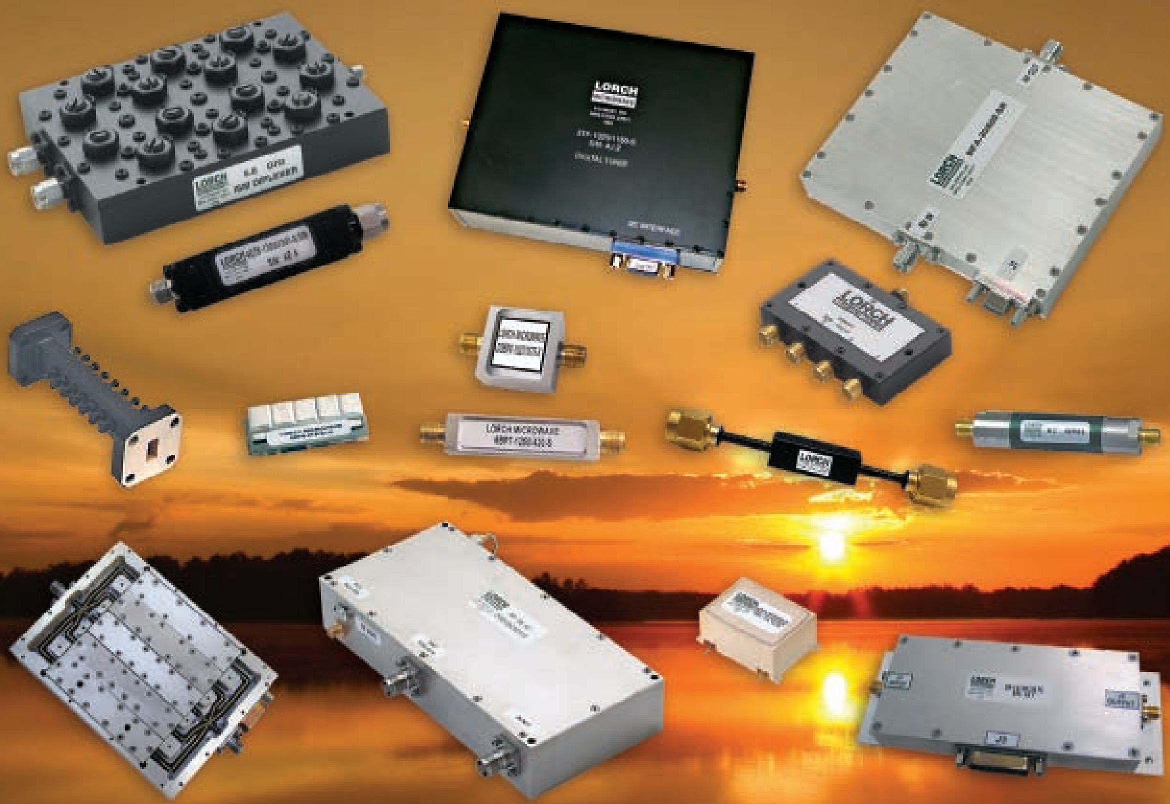
EgyptAir has selected Rockwell Collins avionics for five A330 aircraft with an option for three additional aircraft. Deliveries are scheduled from August 2010 through 2012.

The agreement includes Rockwell Collins Multiscan™ Hazard Detection System, TTR-2100 Traffic Avoidance System, as well as a full communications, navigation and surveillance suite including the GLU-925 Multi-Mode Receiver.

“With their selection of the MultiScan Hazard Detection System, our newest Traffic Collision Avoidance system, and advanced Multi Mode Receiver for precision navigation, EgyptAir is equipped with some of the most advanced avionics available to airlines today,” said Jeff Standerski, Vice President and General Manager of Air Transport Systems for Rockwell Collins. “These systems will play an important role in delivering enhanced levels of situational awareness for EgyptAir flight crews, as well as increased operational efficiency for the airline and its passengers.”

The Rockwell Collins MultiScan Hazard Detection System analyzes and determines actual weather hazards, not simply atmospheric moisture content. The MultiScan system is derived from extensive operational experience to create a fully automatic, hands-free airborne radar system that reduces pilot workload, enhances safety and passenger comfort by minimizing unexpected turbulence encounters, and provides optimal clutter-free weather displays.

Rockwell Collins’ new TTR-2100 Traffic Collision Avoidance System (TCAS) is a traffic computer-capable TCAS derived from Rockwell Collins’ integrated surveillance product line, which offers technology that can adapt to the evolving air traffic management requirements.



Partners to Improve European Semiconductor Industry

In order to foster the competitiveness of the European semiconductor industry, 35 European partners have formed the – Implementing manufacturing science solutions to increase equipment productivity and fab performance (IMPROVE) – joint research project. The project runs from 2009 to the end of 2011 and targets the increased productivity of semiconductor manufacturing as well as reducing costs and processing time. The project's aim is to strengthen the European semiconductor industry through the enhanced efficiency of production sites and offers the opportunity for creating new jobs.

The European IMPROVE project includes software enterprises, semiconductor companies with production sites in Europe, chip fab equipment providers and academia from Austria, France, Germany, Ireland, Italy and Portugal. Infineon Technologies AG has a leading role among the chip manufacturers and coordinates the activities of the German partners.

The ever-increasing functionality of new chips leads to high complexity in their fabrication, along with longer production times due to additional processing steps and development times. Today, making a complex chip requires an average of 550 individual process steps, which take approximately 12 to 16 weeks. The typical production run is 50 to 100 wafers after which manufacturers have to reset production tools for the next product. This makes condition monitoring and predictive maintenance essential in order to stay competitive. The monitoring of semiconductor production tools and processed wafers over the whole fabrication line, combined with innovative data-analysis strategies will maximize the output of high-quality wafers.

The IMPROVE project has a total budget of approximately €37.7 M, half of which is carried by the partners. The other half is publicly funded by the European Commission and by national funding of the participating nations through the joint undertaking of the European Nanoelectronics Initiative Advisory Council (ENIAC) as part of the sub-program – SP4 Nanoelectronics for Energy & Environment. The German Federal Ministry of Education and Research (BMBF) is also supporting the project with €3.5 M within the Informations und Kommunikationstechnologie 2020 (IKT 2020) funding programme.

iSLI Develops Aircraft Wireless Sensor System

Engineers at Scotland's Institute for System Level Integration (iSLI) have begun work on the development stage of a £3.3 M project to design a wireless sensor system set to become a standard feature of the next generation of commercial aircraft. The project, which will enable the real-time monitoring of critical components during flight and could make a vital contribution to improved air safety, is jointly funded by the UK Technology Board and some of the aerospace industry's leading companies.

With iSLI playing a lead technical role alongside Rolls-Royce, BAE Systems, TRW Conekt, QinetiQ Ltd., QM Systems Ltd., GE Aviation Systems Ltd., Bombardier Aerospace Belfast, Ultra Electronics BCF, AgustaWestland and Airbus, the WiTNESSS consortium intends to deliver a range of commercial application demonstrators based on the new system by the end of 2011.

The three-year project will initially see the system developed for lifetime maintenance functions and work on the first prototype wireless sensing system has begun. Designed to gather complex and accurate data from different parts of the aircraft—some of which have to be related to one another—makes the design of the whole system more sophisticated than existing wireless devices. The WiTNESSS system will be used to help identify technical faults, optimise performance and monitor the overall health of the aircraft. Also, wireless is a key capability to reduce the costs associated with wired sensor cables.

There is follow on potential for subsequent systems to look at predictive maintenance and ultimately real-time data for safety-critical components. The system is also expected to be of great use in the carbon fibre components being developed to replace aluminium aircraft parts, where sensors can be used to help monitor how they are coping with high pressures and heavy loads and allow manufacturers to get better information about super-structural capacity and the life expectancy of each component. iSLI will retain substantial intellectual property rights emerging from the system, and expects to see the technology exploited by a variety of sectors in the future.

EADS Signs Agreement with Russian Scientific Partners

EADS has signed a long-term partnership agreement with the Russian Academy of Sciences and the St. Petersburg State Polytechnic University (SPb SPU), which expresses the common interests and basic principles of co-operation in Research and Technology (R&T). The agreement is also open for other scientific institutions.

The parties will jointly identify specific R&T projects to be fulfilled by EADS in areas such as advanced simulation capabilities, virtual testing, flight physics, structure and noise reduction. Specific projects in line with these directions will be proposed by a new Research Council, which will be created in the framework of this agreement. With this agreement, EADS is aiming to extend its positive experience in R&T cooperation with its long-term partner, IRIAS, to other institutes. This enhanced network allows the company to move to large scale multidisciplinary projects.

In 2003, EADS established the Russian Technology Office (RTO) to facilitate cooperation with the Russian research and development community. The company currently uses RTO as the focal point for R&T projects with Russian partners. As a locally-based technology acquisition and project management unit, the RTO acts in the interest of EADS and all its divisions. Benefiting from years of experience and well-established relationships in Russia, EADS RTO has developed an effective management approach to project acquisition and management.

Science Access Centres Aid Business Innovative in UK

New centres that offer UK-based businesses flexible and affordable access to cutting-edge scientific equipment and laboratory space for high-tech research and development work have opened at STFC Daresbury Laboratory, part of the Daresbury Science and Innovation Campus in Cheshire, UK.

More than £3 M of cutting-edge equipment is available for businesses to use at the Innovations Technology Access Centres. Through these centres, businesses can develop their innovative businesses by making use of more than £3 M worth of cutting-edge equipment in fully-equipped biological, imaging, materials and physical science laboratories. The laboratories provide a range of flexible and purpose-built research accommodation to suit the needs of a wide range of businesses from 'lock and leave' exclusive use laboratories to multi-user laboratories available on an hourly basis.

As well as having access to high-end laboratory sample preparation and analysis facilities, the centres give businesses the opportunity to work alongside STFC's own highly skilled scientists and leading academic institutions as they carry out their research and development.

The Innovations Technology Access Centres also complement the facilities that businesses can receive from the nearby Daresbury Innovation Centre, which offers high-quality offices and larger leasable space suitable for businesses wishing to set up their own laboratory. The Innovation Centre is already home to over 90 high-tech small businesses employing more than 300 people with specialist expertise in instrumentation, control engineering, medical devices and diagnostics, mobile telecoms technologies and software development.

In-building Wireless Deployment Revenue Will Maintain 21%+ Growth

The economic downturn is likely to cause a slowdown in North American and European in-building wireless (IBW) deployments during 2009-10. ABI Research sees flat growth in those regions for '09-10; however, typical 20 to 25 percent annual growth is expected to return by 2013. Buoyed by constant high growth rates in Asia-Pacific and Middle East/Africa, IBW will post a respectable worldwide revenue growth rate in excess of 21 percent over the same period.

The recession is global in scope: why are North America and Europe suffering more than other regions? The answer, says Senior Analyst Aditya Kaul, is partly in the scale: "In Europe and North America there is a greater proportion of large building deployments (500K sq. ft. and higher) and when those get postponed or scrapped, revenue is hit hard. NA and European operators have also seen their CAPEX being squeezed, which is not necessarily the case elsewhere. Also in APAC and Middle East/Africa cheaper passive systems and repeaters are deployed to a greater extent."

In terms of IBW, some vertical industries fare better than others. In North America particularly, the hospitality and financial sectors have been affected badly. Shopping malls have slowed down as well. "IBW is intimately tied to the real estate market, especially new construction," says Kaul. "As real estate for specific verticals slows there is bound to be some effect on IBW."

In contrast, North American verticals such as healthcare are relatively unaffected. Healthcare is a mature market that has always shown strong growth, and continues to see a high demand for in-building systems that can support not just cellular but also VoWLAN, telemetry, location-based applications and electronic medical records. University campuses are also seeing large IBW activity with some universities investing in their own systems.

VoIP, Cable Gateways and Wireless are Bright Spots in Broadband CPE Market

The recession contributed to 2008 having the slowest total global broadband customer premises equipment (CPE) market growth this decade of 2.4 percent (to 154M units), according to market research firm, In-Stat. 2009 will be even slower. However, cable gateways, wireless and VoIP routers, and wireless and VoIP DSL CPE units continued to grow in at least double digits. In addition, several segments of the broadband CPE market, including cable gateways, Fiber-to-the-Home (FTTH) gateways and Fixed Wireless Broadband (FWB) CPE are expected to grow considerably faster than the overall market over five years.

"Gigabit Ethernet, VoIP, the DSL Forum's TR-69, and 802.11n are all drivers for CPE upgrades and replacements," says Joyce Putscher, In-Stat Analyst. "We're also seeing accelerated growth in FTTH CPE unit shipments in 2009."

Recent research by In-Stat found the following:

- The overall broadband CPE market includes broadband modems, routers, and residential gateway equipment for DSL, cable, Fiber-to-the-Home, Fixed Wireless Broadband, and Fixed Satellite Broadband.
- VoIP-enabled DSL CPE unit shipments saw healthy growth in 2008. More than half of DSL CPE unit shipments will be VoIP enabled in 2009. Worldwide SOHO/Home Routers with VoIP also grew strongly with over 40 percent unit growth.
- The FTTH CPE segment, which includes ONTs and FTTH Gateways, will see a nearly 20 percent Compound Annual Growth Rate (CAGR) through 2013.
- The majority of global FWB subscribers are now WiMAX. Asia/Pacific has the lead in FWB subscribers and CPE shipments, followed by Europe. In 2011, Asia/Pacific should capture over 50 percent share of the annual FWB CPE shipments.
- The research, "Global Outlook for Broadband CPE Through 2013," covers the worldwide market for broadband CPE equipment.

It provides:

- Worldwide and regional CPE markets for broadband modems/ONTs, routers, and residential gateways for DSL, cable, Fiber-to-the-Home (FTTH), Fixed Wireless Broadband, and Fixed Satellite Broadband.
- VoIP forecasts are included for DSL, cable and router equipment, with a regional breakout for cable E-MTAs.
- Wired vs. wireless segmentations are included for routers and DSL residential gateways.
- Global and regional forecasts for installed home networks.
- Consumer survey perspectives about equipment features that impact buying decisions.

One Billion Wi-Fi Chipsets to Ship in 2011 Alone

Wi-Fi seems to be all-pervasive, and in the year 2011 alone, Wi-Fi chipset vendors will ship one billion units, according to market data just released by ABI Research. By the end of the following year a cumulative five billion such chipsets will have shipped since the firm began tracking Wi-Fi chipsets in 2000.

In the near term, says Research Practice Director Philip Solis, "802.11n will be the dominant protocol shipped during 2010, and there will be no looking back as single stream 11n chipsets (those not employing MIMO technologies) increasingly replace 802.11g products."

Wi-Fi is penetrating an ever-widening array of devices. Wi-Fi chipset shipments will total well over 100 million just for smartphones this year, and smartphones, netbooks, and a wide variety of consumer electronics devices such as portable media players, TVs, and cameras will become increasingly important market segments.

"Although ASPs are falling," says Solis, "the market is growing fast enough to keep revenues increasing."

Among other interesting recent industry developments is Qualcomm's entry into this market with a 4x4 MIMO 802.11n chipset.

Meanwhile, Broadcom continues to be the vendor to catch: "Broadcom's market share may fluctuate from quarter to quarter," notes Solis, "but the company continues to remain firmly on top of the Wi-Fi chipset market, and will likely continue to do so for the foreseeable future."

The "Wi-Fi IC Market Data" package provides historical and forecast market data on a quarterly basis. Data and market share figures for the previous eight quarters are included, as are yearly data up to 2012. The database includes annual overall IC market share statistics from 2001 to the present, and market share data for a wide variety of product categories.

Slower Recovery for GaAs Industry

The global economic meltdown slowed year-on-year GaAs industry growth from its previous forecast of 9 percent down to 6 percent in 2008. With the market projected to contract again 5 percent year-on-year in 2009, gains made in 2008 will be effectively wiped out and the GaAs industry is projected to generate revenues of $3.5 B in 2009, according to the Strategy Analytics GaAs annual industry forecast and outlook for the GaAs industry.

"The GaAs industry effectively shut down as handset manufacturers turned off the taps in the final quarter of 2008," observed Asif Anwar at Strategy Analytics. "However, Strategy Analytics believes that the market has bottomed out and multiple GaAs device insertions in cellular handsets will be augmented by demand from other wireless markets as well as requirements from defense, consumer, fiber optic and automotive sectors."

Demand from wireless markets, including cellular handsets, will continue to be the primary growth engine for the GaAs industry. While Strategy Analytics expects growth to return in 2010, with all major end demand sectors growing through 2013, industry revenues will fall short of previous expectations of $5 B. The overall growth will be tempered as a result of the economic downturn and growth will show signs of flattening out in 2013. Overall, the GaAs, RF and microelectronic device market will grow at a CAAGR (compound annual average growth rate) of 4 percent through 2013, to be worth $4.5 B.

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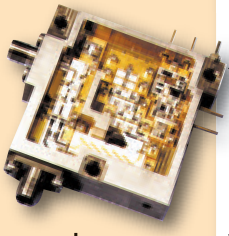

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INDUSTRY NEWS

■ **MI Technologies**, a provider of advanced engineering, wireless, precision instrumentation and measurement systems, announced it has entered into an agreement to purchase the majority of the assets and have exclusive rights to all **IAM System**'s designs and products. Since its inception, IAM Systems has been a designer and manufacturer of microwave reflector systems using the latest metrology and modeling tools. IAM's reflector products are being used throughout the world to make RF measurements. As part of this move, William (Bill) R. Griffin, Jr., IAM's Owner and Principal, will be joining MI Technologies as a Senior Technologist.

■ **Abilis Systems**, a Kudelski Group company, and a pioneer RF semiconductor company, announced the acquisition of **Freescale Semiconductor** CMOS Modulators and Silicon Tuner product lines. The acquisition of these assets will allow Abilis to expand its broad portfolio of leading, silicon-based digital TV (DTV) and tuner solutions and better address the needs of the growing digital TV market, and in particular of Digital Terrestrial (DTT) and cable platforms. It will enable Abilis to support the growth of Pay-TV operators by combining its innovative cutting-edge technology with well-established and proven technology and knowledge from one of the most relevant global chip manufacturers. Furthermore, this extension of product portfolio and related skills and competences will further enhance its expertise in this area with the integration within Abilis of the dedicated team from Freescale.

■ **Murata Manufacturing Co. Ltd.**, an innovator in electronics and a global supplier of ceramic passive components, announced that it has purchased the multilayer ceramic capacitor (MLCC) business from **Panasonic Electronic Devices** (PED). This acquisition increases Murata's international competitiveness in the MLCC market as Murata will acquire PED's technology, distributors and customers.

■ **Anritsu Co.** announced a partnership with **Forward Link**, a division of CBM of America Inc. (CBMA) and a recognized leader in the design, engineering, manufacturing and integration of innovative products and services for the communications industry. The partnership will enhance Anritsu's established position as the market leader in developing innovative RF test solutions that make it easier for wireless field professionals to locate and identify interference, sweep antennas, conduct spectral validation and mapping coverage, as well as other tests.

■ **HRL Laboratories LLC** announced that it has partnered with the National Secure Manufacturing Center at the National Nuclear Security Administration's Kansas City Plant (KCP) to provide multiple-project wafer services to the Department of Defense (DoD) Trusted Foundry Program. The National Secure Manufacturing Center provides the national security community secure manufacturing and engineering solutions.

■ **Agilent Technologies Inc.** announced its collaboration with Southeast University-China to improve mobile communication systems performance. Agilent is providing grants and test instruments for the university's use in researching methods for users to obtain higher data rates and high-quality services with increased spectrum and power efficiency.

■ Effective immediately, **S.M. Electronics LLC** will operate under the name **Fairview Microwave**. The reason is SM is an extremely common name on the Internet. There have been several low cost imitators using similar domain names resulting in confusion among the company's customers. Fairview Microwave is a unique name that will eliminate this confusion. The company's new information: Fairview Microwave, 460 South Highway 5, Fairview, TX 75069, (800) 715-4396, www.fairviewmicrowave.com or e-mail: sales@fairviewmicrowave.com.

■ **Z-Communications Inc.**, a US manufacturer of VCO and PLL modules, announced that the organization's quality management system has been assessed and registered by Intertek Testing Services NA Inc. as conforming to the requirements of ISO 9001:2008. The certification of compliance with ISO 9001:2008 recognizes that the policies, practices and procedures of Z-Comm's organization ensure consistent quality in the products Z-Comm provides its customers.

■ **Laird Technologies Inc.**, a leader in the design and manufacture of customized, performance-critical components for wireless systems and other advanced electronics applications, announced that the Patent Board ranks the company as #17 in Industry Impact, #19 in Innovation Cycle Time and #41 overall in the board's Top 50 Scorecard for Telecommunications—an increase of 16 points from its previous ranking.

■ **ANSYS Inc.**, an innovator of simulation software and technologies designed to optimize product development processes, announced its inclusion on the 2009 *FORTUNE* 100 Fastest-Growing Companies list. ANSYS is ranked number 33 overall, the only engineering simulation provider and the only Pennsylvania-based company to make the list. Of the 24 companies in the technology sector, ANSYS was in the top 10, ranked at number eight.

■ **AVX Corp.**, a manufacturer of advanced passive components and interconnect solutions, received the Arrow Electronics 2008 Largest Passives Supplier award at the 2009 Electronic Distribution Show (EDS). Julie Miller, Supplier Account Manager of AVX, accepted the award from Stephen Sallas, Business Segment Manager at Arrow, at an awards banquet recently.

CONTRACTS

■ **MicroWave Technology Inc.** (MwT), a wholly-owned subsidiary of IXYS Corp., announced that it has been awarded a contract from **BAE Systems** with a total amount of over $2.5 M. The contract consists of supplying a large volume of custom connected microwave amplifiers with military electrical specifications and high reliability requirements.

■ **KOR Electronics** announced a multi-million dollar award from a major international Defense Prime. The contract is for upgrade to a KOR simulator originally developed in 2005. This new contract will dramatically extend the simulator's current features, in addition to providing the end user with testing capabilities that are the most advanced available in today's market.

■ **Microwave Systems Solutions** of Crane Aerospace & Electronics Group, a segment of Crane Co., has announced that it signed a new contract with **Harris Corp.**, Melbourne, FL. Microwave Systems Solutions was awarded a development contract, with potential for annual production of over $3 M, by Harris Corp. to manufacture a Transmit/Receive (T/R) Module for a new program. Under the contract, Microwave Systems Solutions will work closely with Harris Corp. to provide a T/R Module for the War Fighter Information Network—Tactical. This particular product is designed to provide modern/robust voice, data and imagery distribution system for battlefield operations. The production is scheduled to begin in the third quarter of 2009 in Chandler, AZ.

■ **RF Micro Devices Inc.** (RFMD) announced it is supporting the ramp of Samsung's Tocco Ultra Edition and GT-S8000 "Jet" 3G handsets with two of its industry-leading 3G cellular front ends—the RF3267 and RF6266. RFMD's high-efficiency and ultra-compact 3G front ends are designed to support the critical needs of multi-band, multi-mode 3G handsets and smartphones.

■ Wireless RF semiconductor company **RFaxis** announced that it has scored design wins with Taiwan-based **CeraMicro Technology Corp.** RFaxis' industry-first RFeICs (RF Front-end Integrated Circuits) will be used in CeraMicro's System-in-Package (SiP) solutions for Zigbee and WLAN.

■ **Harris Stratex Networks Inc.** has signed a contract with **ICOMM**, one of India's leading groups in the field of telecom, power transmission and distribution EPC, solar and infrastructure, to supply, install, commission and maintain an IEEE 802.16e mobile WiMAX network for Bharat Sanchar Nigam Ltd. (BSNL).

FINANCIAL NEWS

■ **TriQuint Semiconductor Inc.** reports sales of $169.1 M for the second quarter of 2009 ended June 27, 2009, compared to $127 M for the same period in 2008. Net income for the second quarter of 2009 was $3.9 M ($0.03/per share), compared to a net income of $3.4 M ($0.02/per share) for the second quarter of last year.

NEW MARKET ENTRIES

■ **Rohde & Schwarz**, a supplier of RF test and measurement equipment, has developed its first family of broadband amplifiers. The company leveraged its extensive expertise as a broadcast transmitter manufacturer to design the new product line. As a result, the R&S BBA100 is the most flexible and advanced broadband amplifier system on the market. Its modular design allows users to select frequency range and output power to suit their requirements. The built-in expansion capability protects capital investment. Individual amplifier modules can be replaced quickly and easily, making downtime a thing of the past. The R&S BBA100 is ideal for EMC applications in test houses and the electronics and automotive industry. The high quality and reliability of the amplifiers will also benefit research institutes, development labs and government agencies, as well as radiocommunications applications.

■ **ENS Microwave LLC** announces that it has opened business as a small, woman-owned manufacturer of high performance flexible and semi-flexible microwave cable assemblies. Kristen Schretzenmayer, formerly VP of Operations at IW, Microwave Products Division, has assembled a staff with over 50 years experience in the interconnect industry. ENS offers a wide range of cable and connector combinations from DC to 60 GHz with typical lead times of less than four weeks and can design special connectors to be used within any particular application and can utilize almost any cable type commercially available. The company specializes in custom assemblies built to customers' specifications with products found in the telecommunications and aerospace industries and address the stringent reliability, environmental, and performance requirements of the RF industry.

PERSONNEL

■ Valpey Fisher Corp. announced that the Board of Directors elected **Gary Ambrosino** and **Steven Schaefer** to its Board of Directors as well as the appointing of **Mario Alosco** as Secretary of the corporation. Ambrosino is the Managing Director of clearValue strategies, a consulting firm based in Boston, MA, that specializes in strategic development and tactical execution of new product programs. Schaefer is the President of Cobham Sensor Systems Strategic Business Unit. He has over 30 years of experience in the Aerospace and Defense Industry and an extensive background in engineering, business development, program management and finance. Alosco, a Director of Valpey Fisher since 2004, was named Secretary of the corporation. From September 2005 he has been an Executive Search Consultant and Partner at Mainstay Partners.

■ M/A-COM Technology Solutions Inc. (M/A-COM Tech), a supplier of semiconductors, active and passive components and subassemblies for RF, microwave and millimeter-wave applications, announced that **Robert (Bob) Donahue** has joined the company as Chief Strategy Officer. Donahue is responsible for leading M/A-COM

▲ Bob Donahue

Tech's efforts in targeting faster growth markets where the company's technology provides a competitive advantage. He will also work with the product line managers on new product and technology roadmaps. Additionally, he will oversee the company's channel and strategic account plans. Donahue has a rich background in the RF and microwave industry. Most recently he was Executive Vice President of Sales and Marketing, Business Development and Chief Strategy Officer at WIN Semiconductor.

■ Duplex CSA Ltd., a supplier of low cost RF connector solutions and shielding products, announced the appointment of **Dave Gravina** as Business Development Manager Americas, **Steve Bearns** as Business Development Manager Asia and **Paul Hulatt** as Group Project Manager. In the positions of Business Development Manager, Gravina and Bearns are responsible for coordinating new business opportunities in their respective regions. Rosa Fearria continues in her role as the Business Development Manager for Europe. As Project Manager, Hulatt is responsible for the support of ongoing business running with major customers as well as working on marketing and the company's key product initiatives. Bearns has a long standing relationship with Duplex CSA since 2004 when he worked for Frontier Silicon and was a customer of Duplex.

■ Entropic Communications Inc. announced that **Tom Lookabaugh** has joined the company as its Chief Technology Officer. Lookabaugh joins Entropic as a seasoned executive with more than 20 years experience in developing communications technology solutions for satellite, cable, telco and broadcast industries. As CTO, Lookabaugh will define and drive the company's technology and advanced architectures roadmap and will support the company's business strategy.

■ MI Technologies announced the appointment of **Zemin Liu** to the position of Sales Manager – Asia reporting to Mike Murphy, Vice President of Sales. In this role, Liu will provide leadership of the company's sales efforts in Asia by providing a broad range of business and technical capabilities in support of MI's aggressive expansion in Asia. Prior to joining MI Technologies, Liu held increasingly responsible roles in the industry with multi-national companies in both the public and private sectors.

■ Empower RF Systems, a manufacturer of solid-state power amplifiers and amplifier-based solutions, announced the addition of senior level RF talent as part of its ongoing commitment to growth and customer support. **Bill Vassilakis** comes to Empower RF Systems with more than 25 years of experience in senior technical leadership roles developing cutting-edge wireless subsystem technologies for amplifiers, antennas, TMAs, filters, and advanced coverage and capacity solutions. He joins the company as Chief Business and Technology Advisor.

REP APPOINTMENTS

■ **Valpey Fisher Corp.** announced the addition of **Sanco Trading (International) Ltd.** to the global sales network as an authorized sales representative and distributor for all of its products in China. Sanco Trading (International) Ltd. represents manufacturers from around the world with its office in Hong Kong. Its parent company, APAT Investment Group, is headquartered in Shenzhen, China. With a strong sales team and a healthy portfolio, Sanco has the expertise and financial strength to succeed in finding high growth opportunities for Valpey Fisher.

■ **Reactel Inc.**, a manufacturer of RF and microwave filters, multiplexers, switched filter banks, and subassemblies to the commercial, military, industrial and medical industries, announced the appointment of **COMP-TECH SALES** as the company's exclusive representative in New York, New Jersey and Fairfield County, Connecticut. For more information about COMP-TECH SALES, please visit www.comp-techsales.com or telephone Russ Muniz at (201) 288-7400.

■ **Asylum Research** and **Intertech Corp.** announced that they have entered into a new distribution agreement that will enable Asylum to extend its global reach and promote its products in the Russian Federation, Belarus, Georgia, Ukraine, Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan, Armenia and Turkmenistan. Intertech, an American export and engineering company that specializes in providing analytical instrumentation and other products to the Former Soviet Union, will sell and support Asylum's complete line of atomic force/scanning probe microscopes.

WEB SITE

■ **Richardson Electronics Ltd.** (RELL) announced the launch of its redesigned corporate website, www.rell.com, aimed at serving the global community of RF, microwave and power conversion engineers. In developing the new site, Richardson Electronics worked closely with the industry's leading suppliers for today's important applications to provide online resources designed to help engineers improve time to market for new products, locate alternative solutions, save development costs, reduce risk and improve design performance.

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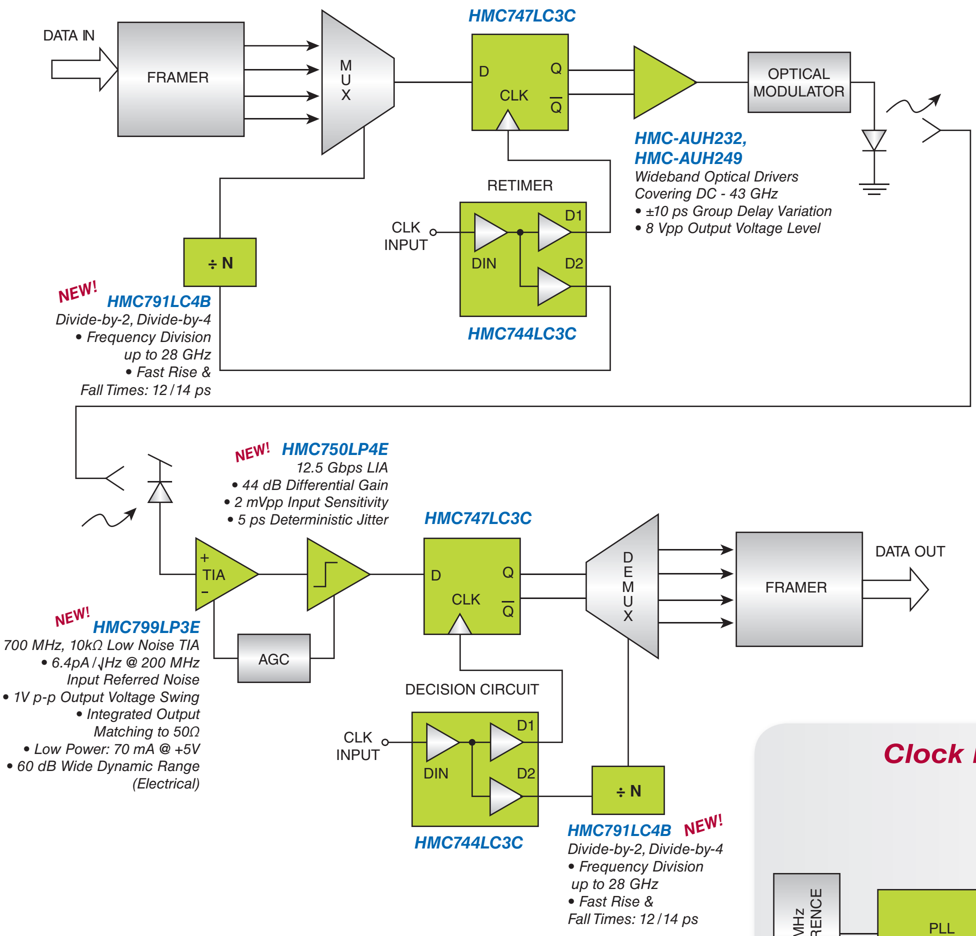

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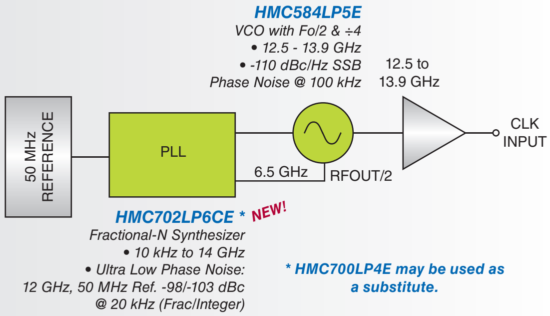

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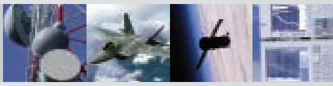

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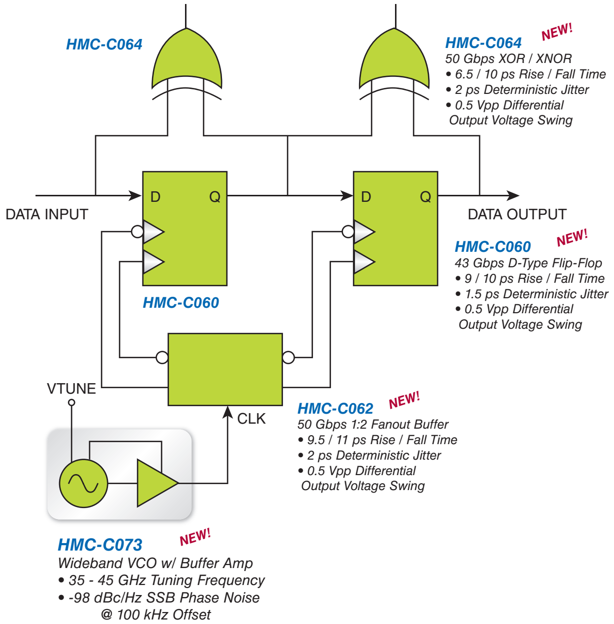
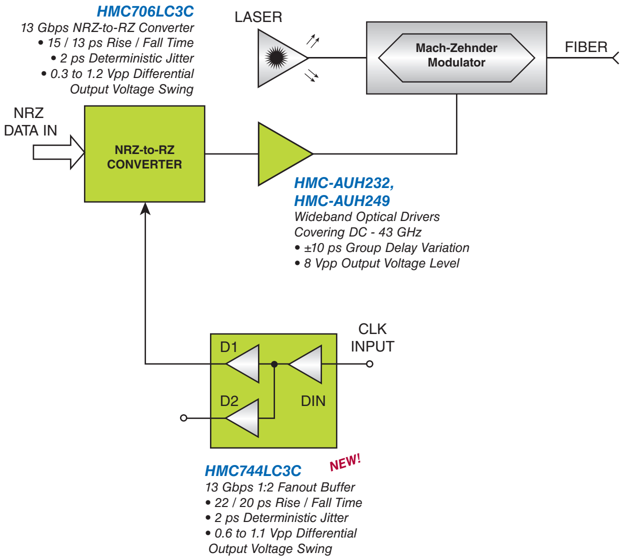
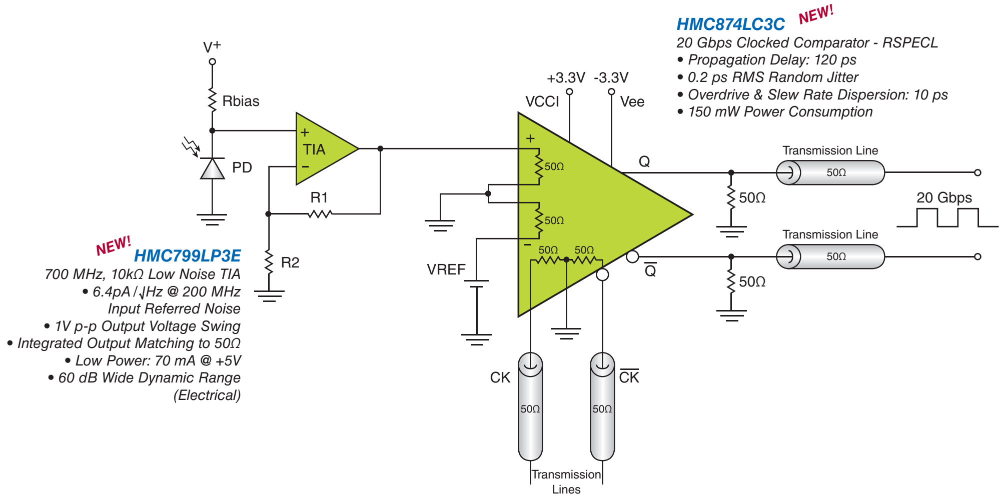


13 Gbps, NRZ-to-RZ Conversion



Limiting Optical Receiver



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RF DESIGN OF AVIONICS L-BAND INTEGRATED SYSTEMS

The last decade has been marked by rapid development in the avionics integrated systems that have important advantages: Fewer units, smaller size, less weight, lower power use, reduced cable count, extensive built-in test equipment (BITE) and integrated maintenance features. This article describes different aspects of RF design of the L-band integrated systems.

Figure 1 illustrates existing L-band Traffic Surveillance Systems (TCAS, Transponder, UAT, ADS-B) and communication/navigation systems (DME, TACAN, GPS, JTIDS/MIDS). The Traffic Collision and Avoidance System (TCAS) located aboard a protected aircraft periodically transmits interrogation signals that are received by transponders located aboard other aircraft, here after referred to as target aircraft, in the vicinity of the protected aircraft. In reply to the interrogation signals, the target aircraft's Transponder transmits a response signal. The TCAS equipment aboard the protected aircraft determines the range of the target aircraft in accordance with the round trip time between transmission of the interrogation signal and receipt of the response signal. Results are provided as displayed data and possibly traffic advisories about potential collision situations. The TCAS uses signals from directional antennas to determine the bearing from the host aircraft to a target (e.g., another aircraft). The TCAS operates on transmit frequencies in the 1030 ±10 MHz range and receive frequencies in the 1090 ±10 MHz range.

The Transponder is an airborne receiver-transmitter portion of air traffic control Radar Beacon System Mode-A and Mode-C interrogations as well as of Mode-S interrogations. The Transponder sends an identifying coded signal in response to a received interrogation from a ground-based radar station to locate and identify the aircraft. Reply signals from the Transponder are used to generate displays of the replying aircraft identification, position and altitude for air traffic controllers. The Mode-S function of the Transponder is used to transmit TCAS-related information between TCAS-equipped aircraft. The Mode-S Transponder consists of the Transponder receiver-transmitter, two omni-directional L-band antennas (top and bottom) and a control panel. The Transponder receives the uplink interrogation pulses at a frequency of 1030 MHz, and sends the downlink reply at 1090 MHz. Automatic Dependent Surveillance-Broadcast (ADS-B) provides real-time, fast update traffic information to pilots who have on-board traffic displays. For most pilots, graphic depiction of traffic is currently unavailable. With each air-

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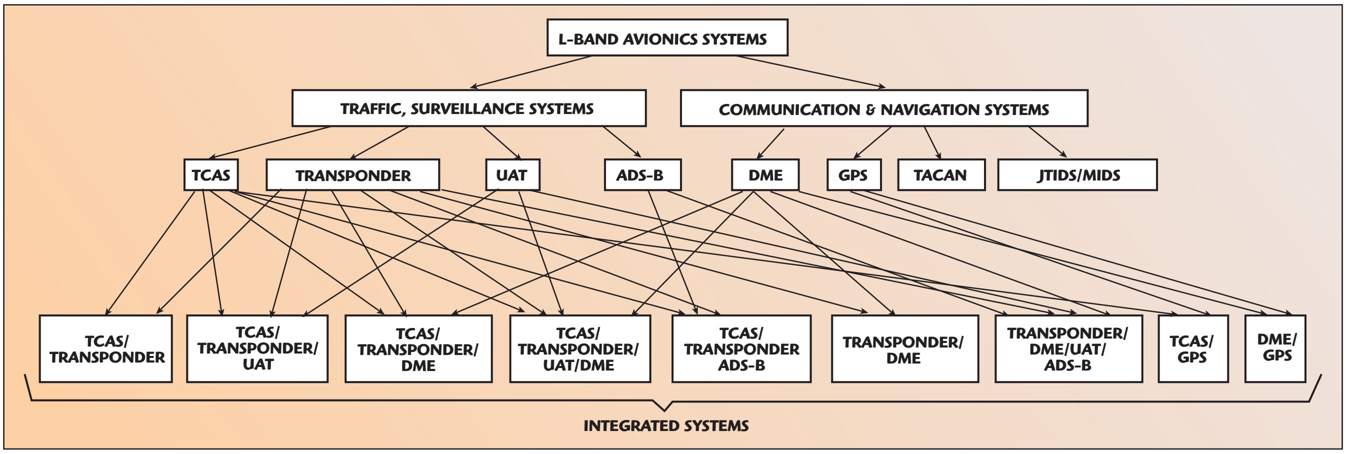


Fig. 1 Existing L-band traffic surveillance systems and communication/navigation systems.

craft's ADS-B system (operating in f = 1090 ± 1 MHz) that receives position reports from other aircraft in the vicinity, pilots will be able to determine not only the position of conflicting traffic, but will clearly see the traffic's direction, speed and relative altitude. ADS-B is viewed as both a surveillance tool and a prime provider of pilot situational awareness. The system also broadcasts a radio transmission from the aircraft approximately once per second containing its position, velocity, identification and other pertinent information.

The Universal Access Transceiver (UAT) is a broadcast data link operating at 978 ±1 MHz. UAT is a transceiver system designed specifically to support the function of ADS-B. UAT is intended to support uplink broadcast data from ground stations. In addition to receiving and transmitting ADS-B signals from aircraft, the UAT datalink system is capable of uplinking and broadcasting data from fixed ground radar stations in two modes: FIS-B (Flight Information Services - Broadcast) mode and TIS-B (Traffic Information Services - Broadcast) mode. FIS-B data includes a wide variety of information, including weather broadcasts (graphical and text), airport status reports, temporary airspace restrictions and official Notices to Airmen called NOTAMs.

TIS-B data includes information about air traffic gathered from ground-based radar systems. The Distance Measurement Equipment (DME) provides position navigation information by measuring the line-of-sight distance between the aircraft and selected DME ground stations, additionally decoding the station identifier and calculating the rate of closure and time to reach a particular station. The DME operates on 252 one MHz-wide channel assignments in the range of 962 to 1213 MHz; each channel having an air to ground frequency assignment in the range from 1025 to 1150 MHz and a ground to air frequency assignment that is either in the range of 962 to 1024 MHz or 1151 to 1213 MHz. The Global Positioning System (GPS) is a United States Government system operated by the Department of Defense. The system provides an aid to radio navigation that uses precise range measurements from the GPS satellites to enable accurate position fixes to be determined anywhere in the world. The GPS L5 signal transmits and receives signals at 1176.45 MHz. The Joint Tactical Information Distribution System/Multifunctional Information Distribution System (JTIDS/MIDS) operates over 51 frequencies between 969 and 1206 MHz. Airborne platforms equipped with JTIDS/MIDS may have top and bottom mounted antennas. ***Figure 2*** illustrates frequency bands of different avionics L-band systems; ***Table 1*** shows the specifications of the L-band avionics systems.

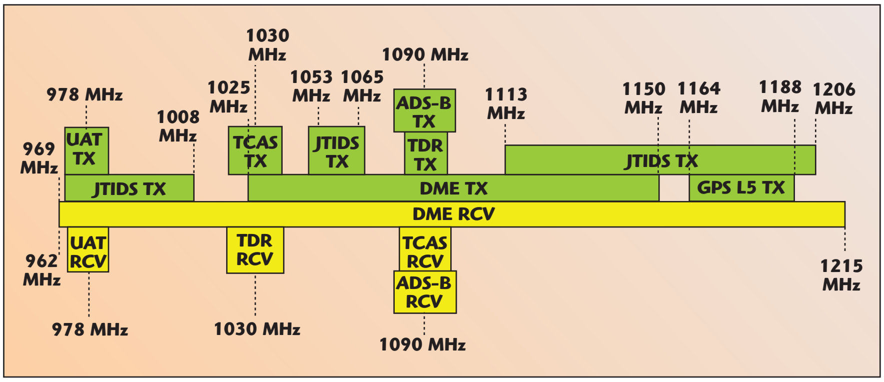


Fig. 2 Frequency bands of different avionics L-band systems.

INTEGRATED L-BAND AVIONICS SYSTEMS

The advantages of the integrated L-band systems (see Figure 1) include smaller size, less weight, lower power use, reduced cable count, extensive built-in test equipment (BITE) and integrated maintenance features. Conventional separate TCAS and Transponder systems require at least four antennas, ten cables, separate receivers and transmitters. Therefore, these systems are heavy, occupy a substantial amount of space and are very costly. The Integrated TCAS/Transponder system includes top and bottom combined antenna modules[1,2] electrically connected to the TCAS/Transponder transmit/receive block to provide directional or omni-directional TCAS or Transponder radiation antenna pattern and directional TCAS and Transponder receive antenna pattern. The characteristics

TABLE I

SPECIFICATIONS OF L-BAND AVIONICS SYSTEMS

	RCV Mode					TX Mode	
System	*Center Frequency (MHz)*	*BW (MHz)*	*MTL (dBm)*	*Dynamic Range, min (dB)*	*Number of RCV Channels*	*Center Frequency (MHz)*	*Power Pulse, min (dBm)*
TCAS	1090.0	6.0	-78.0	68.0	8	1030.0	52.0
Transponder Mode S	1030.0	0.2	-74.0	53.0	2	1090.0	51.0
ADS-B	1090.0	2.0	-84.0	63.0	2	1090.0	53.0
UAT	978.0	2.0	-93.0	80.0	2	978.0	50.0
DME	1090.5	245.0	-85.0	73.0	1	1087.5	55.0

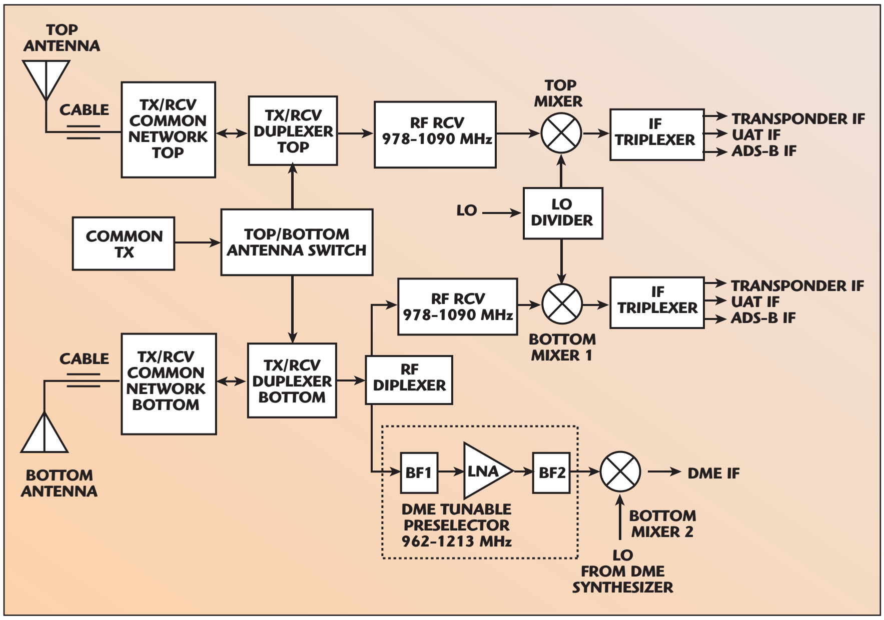
of typical airborne amplitude comparison and phase interferometer directional finding (DF) systems are summarized in referenced material.[3,4]

The conventional TCAS amplitude monopulse system as compared to the phase monopulse system is relatively simple and cost effective, but also relatively inaccurate. To improve a bearing accuracy of the amplitude monopulse system, amplitude calibration and antenna look-up tables (LUT) are used. ***Appendix A*** illustrates the top level RF block diagram of the integrated TCAS/Transponder/UAT system. An option to use a frequency triplexer is provided to allow sharing of a single antenna between the TCAS/Transponder and the UAT unit. The TCAS, Transponder and UAT transmitters are integrated in the common transmitter block. The top/bottom antenna switch/splitter has the following functions: Alternate coupling of the TCAS transmitter with the four top or the four bottom directional antenna inputs to generate format interrogation signals; coupling of the Transponder transmitter with the top or bottom omni-directional antenna during the Transponder transmit mode for transmitting reply signal; coupling of the UAT transmitter and receiver with the top or bottom omni-directional antenna.

Generally, L-band TCAS, Transponder and DME systems employ separate antennas, receivers and transmitters. Thus, each aircraft may include a top and bottom TCAS antenna, top and bottom Transponder antenna, and bottom DME antenna. The total number of TCAS, Transponder and DME antennas of one aircraft is at least five: Top and bottom TCAS antennas, top and bottom Transponder antennas, and one bottom DME antenna. The total number of cables between antennas and the transmit/receive network is at least 11: Eight cables for the top and bottom four-monopole TCAS antennas, two for the Transponder top and bottom antennas, and one for the bottom DME antenna. The main disadvantages of these separate systems are high complexity, cost, size and weight. There are possibilities of an integrated TCAS/Transponder/DME system. Sharing a common antenna between the TCAS, Transponder and DME systems in an aircraft may be desirable to minimize antenna installation cost and complexity.

In the integrated TCAS/Transponder/ADS-B system, TCAS equipment that is capable of processing ADS-B messages may use this information to enhance the performance of TCAS, with techniques known as "hybrid surveillance". As currently implemented, hybrid surveillance uses reception of ADS-B messages from an aircraft to reduce the rate at which the TCAS equipment interrogates that aircraft. The ADS-B messages will also allow low cost technology to provide real time traffic information in the cockpit for small aircraft. ADS-B is used only to identify aircraft that can be safely interrogated at a lower rate. In the future, prediction capabilities may be improved by using the state vector information present in ADS-B messages. Also, since ADS-B messages can be received at a greater range than what TCAS normally operates at, aircraft can be detected earlier by the TCAS tracking algorithms.

The integrated Transponder/DME/UAT/ADS-B system (see ***Figure 3***) provides low cost, smaller dimensions



▲ *Fig. 3 Block diagram of integrated transponder/DME/UAT/ADS-B system.*

and weight and greater reliability. The top RCV channel provides receiving of the Transponder, UAT and ADS-B signals while the bottom RCV channel is used for receiving of the Transponder, UAT, ADS-B and DME signals. In the bottom RCV, the diplexer splits the broadband DME signals from the Transponder, UAT and ADS-B signals. For this combined system, cost is the dominant factor. This combined system requires a multi-channel receiver front-end, which makes allowance for, on one hand, a large number of receiving channels each with a large dynamic range, and on the other hand, low cost, small volume, low weight and low dissipation of these receiving channels. The combined system receiver consists of three channels (1090 MHz ADS-B, 1030 MHz Transponder and 978 MHz UAT) assigned to the top antenna and four channels assigned to the bottom antenna—the same three channels identified above plus the DME channel (960 to 1215 MHz). The same antenna (blade types) can be used for DME, Transponder, UAT and ADS-B. A common front-end receiver should be designed to satisfy different sensitivities or minimum trigger level (MTL) (see Table 1) for the Transponder: -74 dBm; for DME RCV: -85 dBm; for UAT RCV: -93 dBm; and for ADS-B: -84 dBm. To satisfy these requirements the combined integrated front-end receiver should provide different subsystem channel sensitivities. Depending on the UAT equipment class of the installation, the UAT will require either one or two antennas.

Existing L-band systems (TCAS, DME) can provide a redundant navigation system alongside the GPS during the transition to a sole-means GPS national airspace system. TCAS provides the data link for differential GPS corrections through the Mode-S Transponder. With Mode-S being proposed as a national aeronautical data link system, the system may be an effective GPS for a large segment of the aviation community. As the FAA moves to a sole-means GPS NAS, the need for the existing radio-navigation infrastructure will diminish.[5] The total navigation suite would consist of a GPS receiver and a DME-DR system.

RF DESIGN OF INTEGRATED SYSTEM

RF circuits of the avionics integrated systems have some advantages, including low cost; low volume and weight; common antenna module; common transmitter; and single multi-channel receiver. The combined RF systems require a multi-channel receiver front-end, which makes allowance for, on one hand, a large number of receiving channels each with a large dynamic range, and, on the other hand, low cost, small volume, low weight and low dissipation of these RCV channels.


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TABLE II

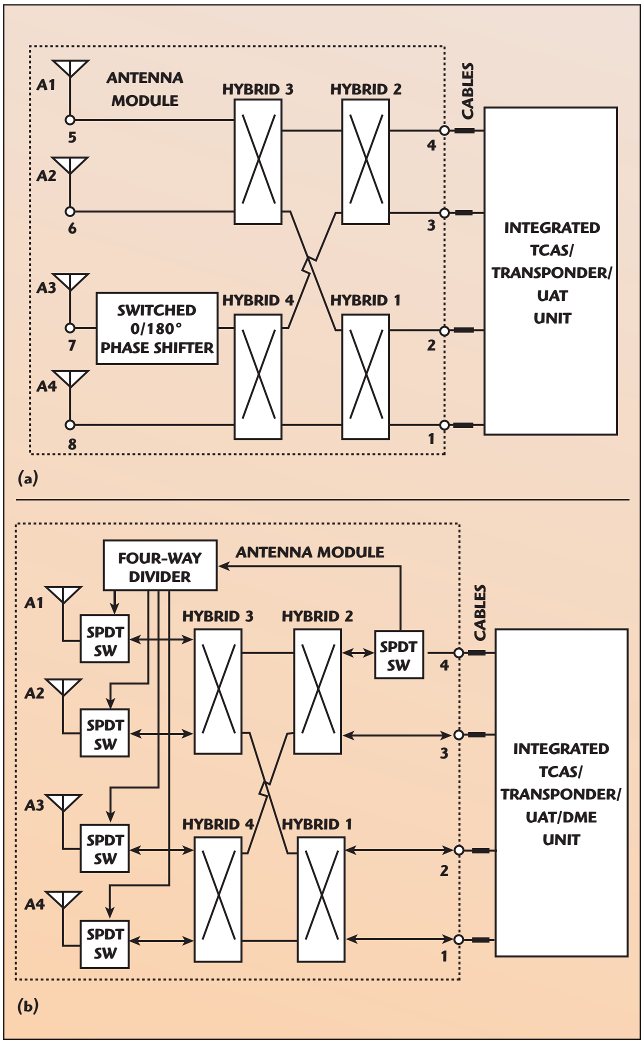
ANTENNA MODULE SPECIFICATIONS

	Antenna Specifications				
Integrated L-band System	***Modes***	***Type***	***Center Frequency (MHz)***	***Bandwidth (%)***	***No.of Connectors***
TCAS/ Transponder	Directional & Omni-directional	Four-monopole	1060.0	6.0	4
TCAS/ Transponder/UAT	Directional & Omni-directional	Four-monopole	1034.0	11.0	4
TCAS/ Transponder/DME	Directional & Omni-directional	Four-monopole	1088.5	23.5	4
TCAS/ADS-B	Directional & Omni-directional	Four-monopole	1060.0	6.0	4
Transponder/DME	Omni-directional	Blade	1088.5	23.5	1
Transponder/ DME/UAT/ADS-B	Omni-directional	Blade	1088.5	23.5	1

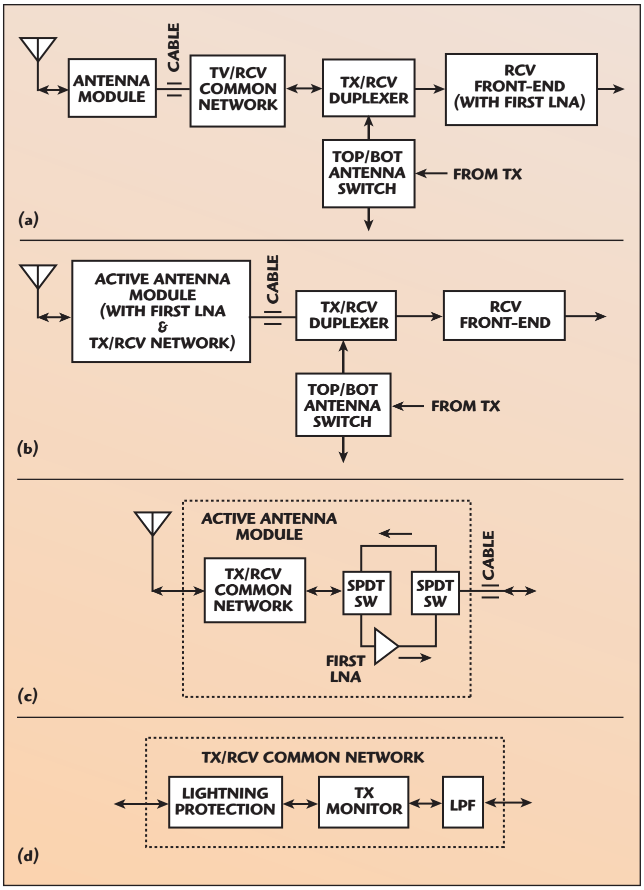
Table 2 illustrates antenna module specifications for different integrated avionics L-band systems. The antennas of the integrated systems including TCAS can be operated in two configurations. The top antenna module must provide the directional and the omni-directional modes. The bottom antenna module may be either likewise directional/omni-directional or sometimes omni-directional only to reduce cost. In integrated systems without TCAS (Transponder/DME; Transponder/DME/UAT/ADS-B), the typical antenna is a vertically polarized metal blade with one BNC or TNC connector. Most of the L-band blade antennas are thin blades about a quarter wavelength in height due to aerodynamic considerations.

The conventional TCAS phase array antenna produces a vertically polarized directional or omni-directional radiating pattern when driven by excitation signals of appropriate phase. Each antenna element (monopole) is independent of the others and is connected to the transmitter/receiver through its own coaxial connector. This special beam steering network provides for different positions of the antenna pattern in the polar system. In an integrated system with TCAS, a multi-monopole antenna array is required. An antenna array configuration depends on the type of system used—phase monopulse system vs. amplitude monopulse system. Due to the poor bearing accuracy of the amplitude monopulse systems, the TCAS requires special amplitude calibration and antenna LUT to satisfy the bearing accuracy requirements.

For the amplitude monopulse system, the special antenna switched beam forming network (SBFN) with a relatively narrowband switched 0/180-degree phase shifter (see ***Figure 4a***) is used.[6-9] The L-band antenna module provides the directional antenna patterns by using a special SBFN that includes a 4×4 hybrid matrix. Four 90-degree hybrids are serially interconnected to form the 4×4 hybrid matrix. Ports 5, 6, 7 and 8 of the hybrid matrix are connected to antenna monopoles A1, A2, A3 and A4, respectively, and the other four ports 1, 2, 3 and 4 are connected to the integrated unit by cables. The eight-port hybrid matrix is used in the SBFN to provide equal amplitudes and specific relative phases for the four antenna monopoles. The directional transmit mode is implemented by the alternate activation of input ports 1, 2, 3 and 4 of the SBFN while the switched phase shifter provides 0 degree phase shift. Each of the four antenna module inputs corresponds to a beam in one of four directions: Front (F), right (R), aft (A) or left (L). During the omni-directional transmit mode only, one terminal (2) is activated while the switched phase shifter is controlled to be at the 180-degree position. During the receive directional mode, which provides bearing measurement, all four of the antenna connectors are monitored while the switched phase shifter is at the 0-degree position. The relative signal intensity from four SBFN ports 1, 2, 3 and 4 show azimuth direction of a selected object



▲ *Fig. 4 Block diagram of amplitude monopulse antenna module (a) and broadband antenna module (b).*



▲ *Fig. 5 Block diagram of conventional RF module (a), active antenna module (b), RCV network (c) and typical RF TX/RCV common network of combined avionics systems.*

according to the special bearing algorithm (index) and antenna LUTs.[6] This RF network can be used for the narrowband integrated systems: TCAS/Transponder; TCAS/Transponder/UAT or TCAS/Transponder/ADS-B.

The main disadvantage of the amplitude monopulse antenna module (see Figure 4a) is the difficulties of the omni-directional mode for the integrated systems including DME due to their wider bandwidth (BW=23.5 percent). The narrowband switched 0/180-degree phase shifter limits the bandwidth of the integrated system. ***Figure 4b*** illustrates the broadband antenna module block diagram[1] without the narrowband switched phase shifter. This antenna module can be used for the relative broadband integrated systems (TCAS/Transponder/DME or TCAS/Transponder/UAT). During the transmit omni-directional mode (for Transponder, DME), the transmit signal passes from the integrated unit through one cable, terminal 4, SPDT switch and four-way divider to the four monopoles. The broadband divider can be implemented using conventional Wilkinson dividers or directional couplers. The four-way divider and BFN are located close to the antenna monopoles to minimize phase and amplitude imbalance between the four terminals of the antenna module. The TCAS directional transmit mode is implemented by the alternate activation of input ports 1, 2, 3 and 4 of the BFN. The position of the antenna pattern depends on which input is activated. During the receive directional mode that provides bearing measurement, all four of the antenna connectors are monitored, and receive signals pass through the four SPDT switches and BFN to the integrated broadband unit.

The novel four-folded monopole antenna is described in the references.[6-8] This antenna can be used for integrated avionics systems including TCAS. The most important future of this antenna array is the possibility of both directional and omni-directional modes, good electrical performance, low profile and weight. As a result of using this antenna configuration with the SBFN, the integrated systems TCAS/Transponder/DME and TCAS/Transponder/UAT includes the two antenna modules (top and bottom), eight cables, and eight receiver channels instead of five antennas, 11 cables, and 11 receiver channels of the existing three separate systems. The antenna module performance depends on antenna configuration, beam forming network, switching circuit and matching network.

Figure 5a illustrates the block diagram of the conventional top level RF module. Consider the specific circuits of this block diagram: Antenna module, common TX/RCV network, duplexer, front-end receiver and switch. The conventional TCAS antenna modules are passive devices, where the front-end receivers connected after the lossy cables have low sensitivity and therefore an aircraft

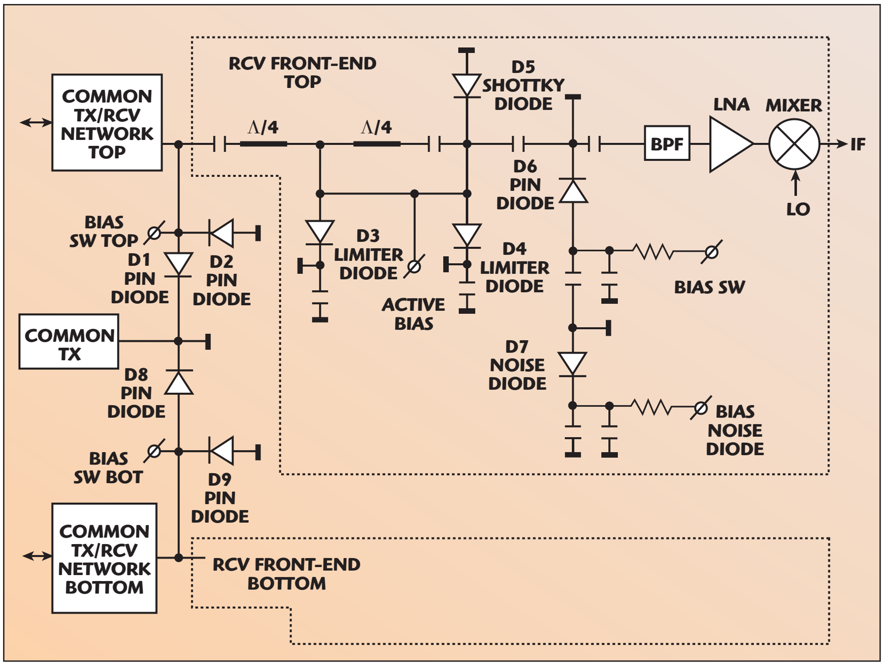
range measurement is limited. The position of the first LNA in the receiver front-end block (Figure 6a) limits the minimum noise figure (maximum sensitivity) due to insertion loss of the circuits before the LNA. For example, according to the reference,[10] the existing avionics cable has a maximum loss of 3 dB. Also, the cable matching might be up to VSWR = 1.7 that lowers the electrical performance of an antenna SBFN. To eliminate these disadvantages in high sensitivity avionics systems, an active antenna module with an LNA can be used. ***Figures 5b*** and ***5c*** illustrate top level block diagrams of the active antenna module and RCV network.

Figure 5d illustrates the typical RF TX/RCV common network of combined avionics systems that includes the following blocks: Lightning protection, TX monitor and low pass filter (LPF). The TransGuard Transient Voltage Supressor provides protection of the front-end receiver from voltage transient caused by lightning. In the LPF, all frequencies of TX and RCV below a set frequency are selected, and all frequencies above this same set frequency are eliminated. Usually, in avionics systems, the LPF is the stepped-impedance circuit that has poor electrical performance due to relatively low Q-factor of the microstrip line. A lower loss LPF can be implemented using a combination of microstrip and suspended substrate lines.[10] Reduction of size and harmonic signals can be realized in the LPF with the defected ground structure (DGS).[12,13]

Most L-band avionics systems have a common transmit/receive antenna, which is why the transmitter/receiver network should include an RF duplexer. An RF transceiver duplexer connects the single antenna to the transceiver. There are three main types of duplexers in common use.[14] The first duplexer consists of an SPDT transmit/receive switch/limiter. The second type includes a ferrite circulator, and the third includes a ferrite circulator and a transceiver protector. The comparison[13] shows that the duplexer with a circulator has several disadvantages as compared to the TX/RCV switch. Its only advantages are good TX peak power and protection of TX from unwanted reflected synchronous signals. During the transmit mode, the switch provides sufficient isolation in the receiver port to protect the receiver front-end from damage. During the receive mode, the switch isolates the transmitter from the antenna and connects it to the receiver.

The transceiver protector in L-band avionics integrated systems provides: 1) protection of the receiver from large input signals while allowing the receiver to function normally when these large signals are not present; and 2) protection of the transmitter from signals reflected from the receiver due to receiver and antenna mismatch. In the duplexer with a circulator, the transmitter power may leak into the receiving system due to non-ideal circulator isolation, antenna port reflection paths, as well as to mutual coupling between adjacent antenna array elements. This can cause such problems as saturation, gain compression of the receiving system and increased FM-AM noise. Also, sometimes unwanted and potentially damaging high power signals from nearby systems (non-synchronous signals) received by the antenna pass to the receiver. There are three types of transceiver protector configurations: Active limiter, passive limiter and quasi-active limiter.[14] Several functions of a transceiver protector can be combined.

Figure 6 illustrates the multifunctional RF schematic with the following three functions: Transmit-receive switching (duplexer function), limitation of the strong parasitic RF signals and self test. The switching function is to connect the antenna to the transmitter in the transmit mode and to the receiver during the receive mode. This switch includes the series shunt circuit with diodes D1, D2 in the transmit pass, and the series shunt circuit with shunt diodes D3, D4 in the receive path. During the transmit mode the switch should have sufficient isolation in the receiver port to protect the receiver from parasitic signals. The limiting function provides protection of the LNA and the mixer from strong RF parasitic signals. While the system is not powered, protection from strong outside parasitic RF signals is provided by limiter diode D3 and by limiter diode D4 with Schottky diode D5, commonly referred to as the



▲ *Fig. 6 Multifunctional RF schematic.*

cleanup stage.[11] While the system is powered, the first and second limiter diodes are active (forward biased) and provide protection of the receiver front-end from the TX leakage. The self-test function can be implemented by the combination of a noise source network and an RF power monitor circuit for control receiver elements. The noise network is located after the switch/limiter network because a noise diode should be protected from the strong parasitic signals. In the self-test mode, when the network (see Figure 6) is not powered, noise diode D7 generates noise for receiver testing and drive PIN diode D6 is forward biased. As a result, the noise signal generated by diode D7 is coupled through diode D6 and applied to the receiver for the receiver self test.

All combined integrated systems have top and bottom antenna modules that are switched by the special top/bottom antenna switch/splitter. The peak power transmitted from the selected antenna should exceed the power transmitted from the non-selected antenna by at least 20 dB. To satisfy this requirement the top/bottom antenna diversity switch should provide at least 20 dB of isolation. The single PIN diode in the switch transmit path can provide for this requirement, but to satisfy the existing manufacture tolerances and environmental conditions the two PIN diodes in the transmit path may be necessary. The conventional shunt diode switch with the quarter-wave lines between diodes[11] has a narrow frequency band (~10 percent) and can be used in the narrowband integrated systems (see Table 1). For the wideband integrated systems, the top/bottom switches should be modified. The broadband switches are implemented with the additional transformers,[15] series PIN diodes, or series-shunt PIN diodes (see Figure 6).

There are two possible configurations in the superheterodyne receiver front-end. The placement of the LNA before the bandpass filter (BPF) gives a better receiver cumulative noise figure, but leaves the LNA unprotected from the out-of-band interfering signals. Also, the BPF placed at the LNA's output rejects the image noise that is created by broadband noise from the LNA. This configuration of the front-end receiver can be improved by the implementation of good rejection of the input LPF and an additional quasi-active and/or active limiter to provide better rejection from the out-of-band interfering signals. If the BPF is the first block followed by the LNA (see Figure 6), noise power will be directly converted into the IF band without filtration between the LNA and the mixer. In this case, cumulative noise figure is higher than the first block diagram, but the LNA is protected from unwanted in-

terfering signals. Placing the BPF before the LNA limits the bandwidth of the input spectrum to minimize intermodulation and spurious responses.

An electrically tunable preselector is a key element in the integrated systems including DME (TCAS/Transponder/DME, Transponder/DME/UAT/ADS-B) (see Figure 3). The main purpose of the DME tunable preselector is the highly selective response to prevent large off-channel signals from overloading the receiver front-end and degrading sensitivity. To minimize receiver noise figure, the RF preselector filter is split into sections separated by an LNA.[11] The first two-pole filter before the LNA prevents undesirable signals from over-driving the LNA. The second three-pole filter placed after the LNA provides selectivity against receiver image and spurious frequencies. The three-pole filter placed after the LNA has a negligible effect on the overall preselector input NF. The passband of the tunable filter should be at 20 MHz, securing 10 times the reduction of noise and interference in the DME 960 to 1215 MHz frequency range. The electrically tunable BPF[11] consists of the suspended substrate resonators, which are grounded at one end, high Q-factor GaAs varactor diodes, and lumped-element loading capacitors between the other end of each resonator and ground plane.

A diplexer/triplexer is an important component for channel separation in receiver channels of combined systems. A diplexer/triplexer provides isolation between receive channels by assigning a different frequency band to each channel. Usually, the minimum and maximum attenuation in the passband should be different by no greater than 0.2 dB. The VSWR produced by the diplexer/triplexer at the unit port, when the other ports are terminated in a 50 ohm load, should not exceed 1.3:1 for frequencies within the passband. A diplexer/triplexer should provide a minimum isolation of 40 dB between unit ports. Triplexers (see Figure 3 and Appendix A) can be used for separation of three output IF channels. A triplexer is formed by connecting three IF bandpass filters. Note that each filter can be designed individually to yield the desired passband before combining the three into a triplexer. Conventionally, design of a triplexer comprises two steps. The first step is to design useable IF filters; the second step is to combine the designed filters together by using the matching network.

An RF network of integrated systems can include two-, three- or four-way splitters. The following electrical parameters of a splitter are significant: Insertion loss, isolation, matching and intermodulation distortion. In transformer splitters with ferrites, intermodulation distortion is sometimes a critical issue. Distortion is caused by saturation of the transformer, usually of the toroidal type, especially at the high frequency end. Also, most transformer splitters require external components (resistors, capacitors) to provide acceptable splitter performance and a reduction in package size. A low-cost N-way splitter can be implemented with the Wilkinson power divider,[11] which provides matching of all ports, low loss and acceptable isolation between output ports. The simplest Wilkinson divider consists of two segments that have the electrical length $\Theta = {}^{2\pi l}/_{\Lambda_0} = 90°$ or the physical length $l = {}^{\Lambda_0}/_4$ (Λ is the mid-band guide wavelength) and lumped resistor R between the outputs of these segments. The conventional L-band Wilkinson divider is relatively large. To reduce size, the ${}^{\Lambda_0}/_4$ segments of the divider can be substituted with an equivalent lumped element circuit.[10]

In integrated aircraft system applications, the trade-offs between physical and electrical properties are important design considerations. Trade-offs pertain to the following attributes: Electrical performance, cost, size and weight. The integration quality of the L-band avionics systems can be characterized by the integration index. The system integration index I_S is determined by the ratios of the number of antennas N_A^{int}, cables N_C^{int}, transmitters N_{TX}^{int}, and receivers N_{RCV}^{int} of the integrated system to the number of antennas N_A^{sep}, cables N_C^{sep}, transmitters N_{TX}^{sep} and receivers N_{RCV}^{sep} of the individual (separate) systems (i_A, i_C, i_{TX} and i_{RCV}):

$$I_S = i_A + i_C + i_{TX} + i_{RCV},$$

$$\text{where } i_A = \frac{N_A^{int}}{N_A^{sep}};\ i_c = \frac{N_C^{int}}{N_C^{sep}};$$

$$i_{TX} = \frac{N_{TX}^{int}}{N_{TX}^{sep}};\ i_{RCV} = \frac{N_{RCV}^{int}}{N_{RCV}^{sep}} \quad (1)$$

For the TCAS/Transponder/UAT/DME integrated system, the system integration index is

$$I_s=2/7+8/13+1/4+8/13=1.5 \quad (2)$$

The RF circuits of the integrated avionics systems can be described by the circuit integration index:

$$I_{cir}=\frac{S_a+S_p+S_c+S_f}{S_a+S_p+S_c} \quad (3)$$

where S_a, S_p, S_c, S_f are normalized areas of active devices, passive components, control devices and free space, respectively. The real circuit integration index I_{cir} of existing L-band systems is between 1.05 and 1.4. The structure of a compact RF circuit can be implemented as multilayer design, three-dimensional design, or vertical-horizontal design.[11] The total integration index is

$$I_\Sigma=I_s\times I_{cir} \quad (4)$$

The minimum integration index $I_{\Sigma min}$ is optimal and indicates the smallest physical dimensions with acceptable electrical performance and reliability. ■

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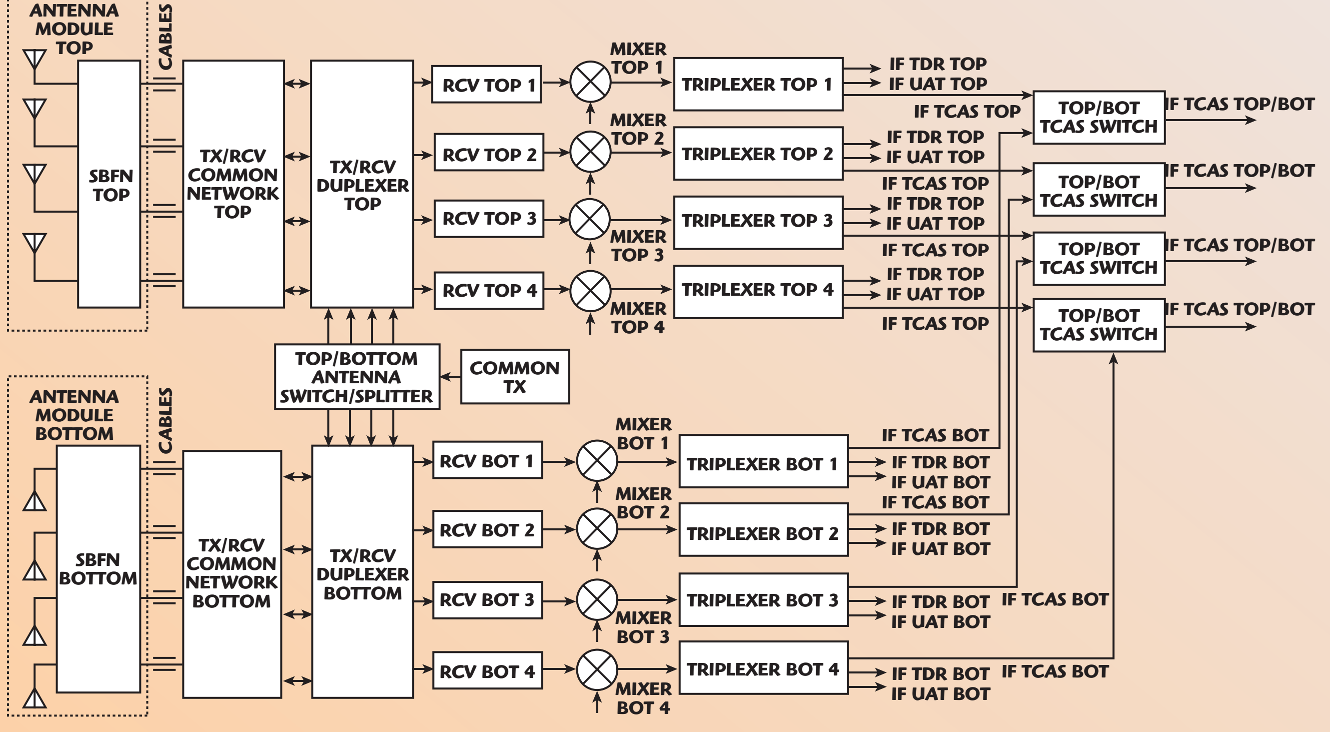
Leo G. Maloratsky *received his MSEE degree from the Moscow Aviation Institute and his PhD degree from the Moscow Institute of Communications in 1962 and 1967, respectively. Since 1962, he has been involved in the research, development and production of RF and microwave integrated circuits at the Electrotechnical Institute, and was Assistant Professor at the Moscow Institute of Radioelectronics. From 1992 to 1997, he was a Staff Engineer at Allied Signal. From 1997 to 2008, he was a Principal Engineer at Rockwell Collins where he worked on RF and microwave integrated circuits for avionics systems. He joined Aerospace Electronics Co. in 2008. He is the author of four monographs, one text-book, over 50 articles and 20 patents.*

APPENDIX A

BLOCK DIAGRAM OF THE INTEGRATED TCAS/TRANSPONDER/UAT SYSTEM



Practical Considerations on Wideband Switchmode High Power Solid-state Power Amplifiers

Modern wireless communication systems demand not only high efficient RF and microwave amplifiers, but wideband designs too. Switchmode power amplification classes can provide both benefits simultaneously, but theoretical knowledge must be combined with important practical considerations to get these advantages.

There are important practical considerations that limit the theoretical capabilities of amplification classes explained in the literature, especially in wideband conditions. Even though some technical solutions have been proposed to overcome these practical limits in narrowband designs, the exigent demands of wideband operation turn them useless. In this paper, the most relevant practical considerations that must be taken into account for proper high efficiency switchmode wideband solid-state power amplifier (SSPA) design are analyzed and solutions are proposed for the proper class of amplification implementation.

SSPAs AND LOW LOAD IMPEDANCE

In order to simplify radio transmitters and to reduce the size and complexity of power combiners and splitters, the solid-state industry has designed and released microwave transistors as powerful as possible within the limits of current solid-state technology. At the present, Si and GaAs, and more recently GaN and SiC technologies, dominate the solid-state RF and microwave power transistors market. Regardless, the solid-state technology, maximum power per transistor will always be limited by thermal and electrical limits such as breakdown voltage and balanced heat dissipation.

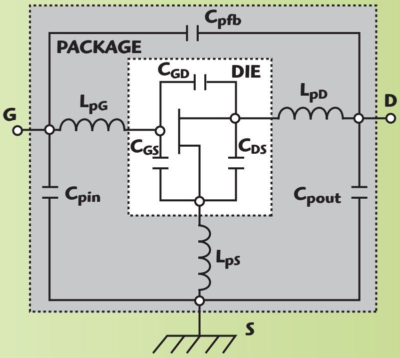
The thermal limits of power RF and microwave transistors are derived from the thermal resistance and heat sinking capabilities of semiconductor materials and packages. These limits can be overcome to some extent by electronic technology using highly efficient switchmode amplification classes because their inherent high power efficiency contributes to reduce heat generated in transistors.

Modern, commercial grade, RF and microwave transistors exhibit breakdown voltages ranging from 50 to 150 V for Si and GaN technologies and lower breakdown voltages for GaAs. These breakdown voltages impose a limit to the power supply voltages of practical SSPAs to about 24 or 50 V, depending on the peak to average voltage ratio of the amplification class chosen to design the SSPA.

Francisco Javier Ortega-González and Jose Manuel Pardo-Martín
Universidad Politécnica de Madrid, Grupo de Ingenieria de Radio GIRA, Madrid, Spain

Breakdown voltage determines the load impedance required by one power transistor to deliver a specific output power level, P_{OUT}, in such a way that the lower the breakdown voltage of the transistor the lower the load impedance required to get a specific output power level P_{OUT}. Using current solid-state technologies, load impedances are typically below 50 ohms at power levels as low as 10 W and below 5 ohms for power levels about 100 W.

Low load impedances and their inherent high current levels are not only related to high power losses, the effect of parasitics (mounting and packaging) are strongly evidenced by high current levels. The correct implementation of any amplification class is difficult in low load impedance conditions, but more specifically the implementation of amplification classes demanding complicated load impedance profiles versus frequency (for instance, Class F). This difficulty increases as frequency and bandwidth increases, making the perfect implementation of any "text-book" amplification class very complicated in practice with maybe the only exception of Class A.



	Value	Reactance @ 200 MHz
L_{pG}	0.4 nH~1.5 nH	+0.5j~+1.9j
L_{pD}	0.4 nH~1.5 nH	+0.5j~+1.9j
L_{pS}	N/A	Negligible
C_{pfb}	1 fF	Negligible
C_{pin}	1 pF~3 pF	–800j ~–265j
C_{pout}	1 pF~3 pF	–800j ~–265j

Fig. 1 Simplified high power RF package model and typical parasitics values.

The most relevant parasitics and practical considerations that make difficult the correct implementation of wideband switchmode amplifiers at RF and microwaves are the following:

a) **Parasitics of transistors' packages:** RF and microwave power transistor packaging is a convenient way to integrate power solid-state transistors in low cost Printed Circuit Boards (PCB) based on plastic laminates. Nevertheless, the packages of power transistors add important parasitics to the dies that heavily affect their electric behaviour not only at microwaves but at frequency bands as low as VHF or high HF. Accurate modelling of power transistors' package parasitics is not simple, nevertheless, for the sake of simplicity. ***Figure 1*** shows an approximate yet effective electrical package model directly extrapolated from the transistor package physical structure.

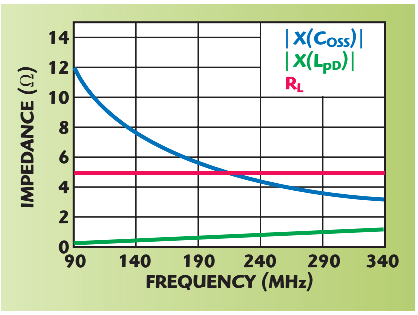
The series inductive parasitic is usually the most disturbing one for the implementation of any class of amplification. The electrical connection from the die to the boundaries of the transistor package is usually made of a set of paralleled gold bond wires and a metallic tab. From a simplified electrical point of view it can be modelled as a 0.4 to 1.5 nH series inductance and a 1 to 3 pF shunt capacitance to ground.[1] Therefore, the reactance of the series inductance of an RF average transistor is about +1j at only 200 MHz. This value is a noticeable fraction of the load impedance required by a power transistor operating on low load impedance conditions. Moreover, this parasitic cannot be easily absorbed by the load network of the amplifier.

One of the most important adverse effects caused by this parasitic is that it is impossible to connect any shunt load (capacitance or inductance) directly to the drain of the transistor. This severe restriction makes the correct implementation of most amplification classes difficult with the only exception, Class A. This restriction is even more noticeable in wideband amplifiers that usually require band-pass derived load networks using shunt components.[2]

Although this article is not focused on driving circuits, it is clear from above that a similar analysis can be performed for the parasitics at the

input of power transistors. From the reasons exposed before, it easy to derive that the possibilities of synthesizing specific driving waveforms suitable for efficient swicthmode amplifier driving at RF and microwaves are severely limited.

Figure 1 shows a simple yet effective electric model for a typical packaged power transistor. Typical parasitic values for approximately 100 W packaged devices intended for under 1 GHz operation are also displayed.



▲ *Fig. 2 Comparison of a Si LDMOS transistor $|X(C_{oss}@24\ V|$, $|X(L_{pd})|$ and R_L.*

b) **Transistor intrinsic output capacitances:** Transistor output capacitance causes two important effects:

- It limits the maximum frequency or bandwidth (for a determinate P_{OUT}) for nominal implementation of amplification classes requiring capacitive or short-circuit load at harmonics, such as Class E, Class C and mixed modes.
- It makes difficult, degrades or precludes in extreme cases, the implementation of amplification classes requiring frequency alternated load impedance versus frequency profiles: Short circuits at even harmonics and open circuit at odd ones (or vice versa). Some clever load circuits have been devised to overcome these effects at least at $2f_0$ and $3f_{0;}$[4] unfortunately, to the best of the knowledge of these authors, those techniques are only effective for narrow bandwidths.

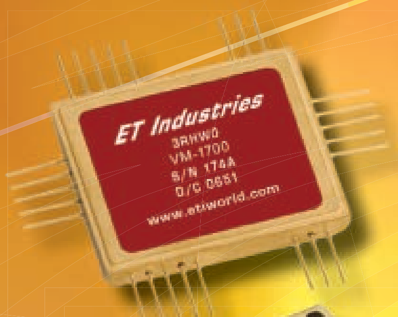
Figure 2 shows a comparison of the module of the reactance of C_{OSS} at 24 V $|X(C_{OSS}$ at 24 V$)|$ of a typical Si LDMOS commercial transistor and the module of the reactance of its inductive drain package parasitic $|X(L_{pd})|$ versus the resistive part of the recommended load impedance R_L for this transistor. As can be observed, both parasitic reactances are noticeable fractions of R_L at only 200 MHz.

c) Effects of lumped component parasitics on the synthesis of SSPA's load networks: Two important figures of merit of passive lumped components (inductors and capacitors) used in SSPA load networks must be considered in SSPA design: Self Resonant Frequency (SRF) and Quality Factor (Q).

Capacitors: Multilayer ceramic or porcelain dielectric capacitors are frequently used in the load networks of SSPAs. For a specific capacitor package, the SRF decreases as capacitance increases; the higher the capacitance the lower the SRF. Regarding Quality Factor Q, this figure of merit usually decreases as frequency and capacitance increases. This peculiar performance causes two important effects:

- The Q versus capacitance profile causes important power losses in the low load impedance environments typical of RF and microwave power transistors for SSPAs.

Modulators Demodulators



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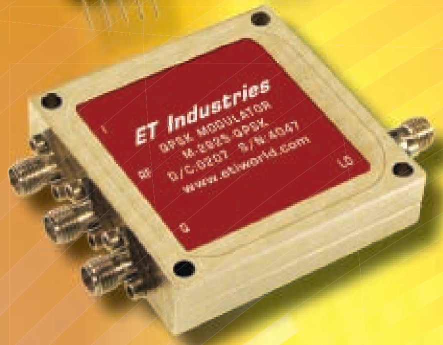

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- The Q versus frequency profile (Q decreases as frequency increases) causes that the power losses of the SSPA load networks at the harmonics are higher than at the fundamental.
- The high value capacitors required by SSPAs at low impedance planes exhibit low SRF values that make the correct synthesis of the load impedance difficult at the harmonics.

Inductances: Q and SRF of inductances are not easily predictable. In addition to ohmic losses, radiation losses have an important role in these figures of merit. Even though it is usually true that the Q of a specific inductor increases as frequency increases (while the SRF is not reached), there is not a direct rule linking Q and inductance.

To illustrate these effects, ***Table 1*** shows the SRF and Q of some SMD multilayer porcelain power capacitors for different capacitances and frequencies and some air core inductances required by the load network of a typical SSPA in the 100 W range. It can be observed that the large capacitors exhibit not only relatively low Q—not much different than the Q of the inductances—but low SRF as well.

TABLE I

SRF AND Q OF MULTILAYER PORCELAIN CAPACITORS USED IN SSPAs LOAD NETWORKS

Capacitor	Q@150 MHz	Q@500 MHz	SRF (MHz)
300 pF	160	26	400
75 pF	400	65	775
33 pF	1020	175	1025
22 nH	130	200	3000
120 nH	120	120	1000

In summary, the effects of component parasitics on SSPAs look "amplified" by the high current levels involved in the typical low load impedance planes required by SSPAs. It can be said that, in some way, the technological problems associated to low load impedance planes typical of SSPAs look like the problems that appear using low power devices at higher frequencies. Therefore, the technology required to work in high output power conditions is not different than the one required at much higher frequencies using low power devices that demand higher load impedances (non-packaged transistors, single layer capacitors, etc.). As a matter of fact, MMIC or hybrid technology is probably the most suitable technology for high power SSPAs at frequency bands as low as VHF to properly implement any amplification class. Nevertheless, SMD technology over plastic PCB laminates is the dominant one because it is inexpensive.

When the power levels delivered by transistors are high and frequency is also high, as happens in RADAR or broadcast applications, the effects of package parasitics are so important that they preclude the correct implementation of any amplification class except for very narrow bandwidths. Built-in matching networks are frequently used to solve this problem, but this solution limits the freedom and possibilities for the designer.

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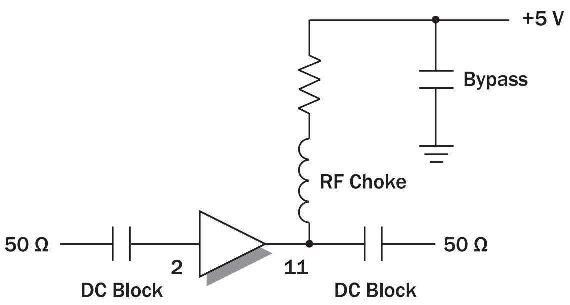
SUF-8533	DC to 12.0	16.8	25.2	14.5	4.2	QFN-16, 3 x 3



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Built-in matching networks (internally matched transistors):
In order to keep the practical advantages of SMD manufacturing technology on plastic laminates with high power amplifiers at frequencies beyond UHF, solid-state manufacturers include built-in matching networks into many of their high power transistor packages, both at their input and output. These built-in networks are impedance transforming networks made of micro lumped elements (MOS capacitor for capacitances and bond wires for inductances) connected next to the transistor die. The main purpose of these built-in matching networks is elevating the input impedance and output load impedance required by transistors, making it easier for the implementation of output load impedance networks and increasing the wideband operation capabilities of the devices.

Nevertheless, transistor built-in matching networks cause some problems and have limits. The possibilities of synthesizing a determinate load impedance profile at the fundamental and harmonics are severely limited by built-in matching networks because the high frequency impedance "trend" of the built-in matching network, located next to the die, imposes the high frequency harmonic "trend" of the load network.[5] Therefore, the possibilities of implementing different amplification classes using transistors fitted with built-in matching networks are limited. As a matter of fact, these "pre-matched" transistors behave like amplifiers rather than simple transistors. Furthermore, built-in matching networks add extra power losses to transistors, contributing to reduce the efficiency of the SSPA using these kinds of devices.

LOAD CIRCUITS

Load circuits are used in SSPAs to provide the proper complex load impedance at the fundamental (usually performing impedance transformation functions), besides providing proper termination at the harmonics.

Impedance transformation tasks are usually carried out by two different types of circuits:
Passive impedance transformation networks based on lumped components and transmission lines[6] or transformers (based on magnetic coupling or transmission line technology).[7] Both types of circuits and devices will be briefly analyzed in the next few subsections.

Impedance transformation networks based on lumped components and transmission lines:
SSPA load networks made of lumped components and transmission lines usually combine the impedance transformation and harmonic termination tasks. When these functions have to be implemented over wide bandwidths (one octave or more), load networks become quite complex, usually requiring more than six elements to achieve an acceptable flat "in-band" response and consequently those load networks cause noticeable power losses.

Low reactance components are required in the load networks of high power transistors. As previously mentioned, these components suffer from low SRF and Q problems, contributing to make difficult the correct load

synthesis at the harmonics and causing power losses. These components also cause circuit repeatability problems because even small value changes and component placing tolerances cause noticeable changes in the synthesized load impedance both at the fundamental and harmonics.

Because of all the reasons mentioned, combining the wideband load impedance transformation and harmonic termination tasks into one load network made of lumped or transmission line elements is not always the best technical solution for high efficiency SSPA loading, especially if the load impedance transformation ratio is high. Not only it is difficult to synthesize the proper load impedance profile required by the SSPA at harmonics, but power losses in the load network can mask the theoretical power efficiency benefits provided by high efficiency amplification classes.

Transformers:

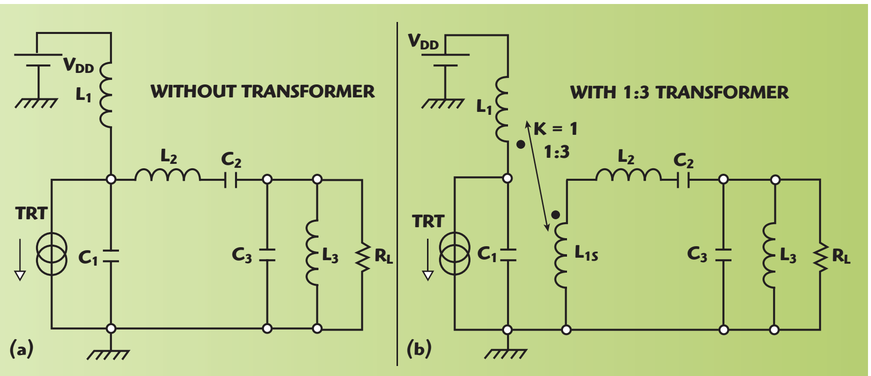
Unlike other impedance transforming devices and circuits, transformers exhibit important practical advantages for SSPA load networks such as wideband operation (ideally infinite), compact size and low power losses, usually lower than the losses caused by equivalent impedance transformation networks based on lumped or transmission line elements. Transformers have been used for decades as impedance transformation devices in SSPAs. Two different transformer technologies are used at RF and microwaves bands: Conventional transformers (magnetic coupling)[8] and transmission line transformers.[7]

With some exceptions (Class A and push-pull Class B) transformers cannot be used alone to implement SSPA load networks; additional harmonic termination networks are required for amplification classes such as Class C, D, E, etc. Separating impedance transformation from the harmonic termination functions in SSPA load networks using a wideband transformer for impedance transformation and a lumped component or transmission line network to provide harmonic termination has proven to be useful and efficient in SSPA load network design techniques[8] that can be used with both conventional and high efficiency amplification classes. This technique relieves the lumped component or transmission line termination network of impedance transformation tasks and allows using it just to provide the proper load phase angle at the fundamental and termination at the harmonics.

Usually only six element networks are sufficient to perform the harmonic termination functions required by any amplification class over bandwidths about one octave, yielding second harmonic rejection better than -20 dBc and bandpass ripple better than 0.1 dB. Because of the low number of components required by these mixed load networks, their power losses are low and can be further minimized if the transformer of the load network is located next to the power transistor and the harmonic termination is cascaded after the transformer (at a higher load impedance plane), as shown in ***Figure 3***. This way the reactance of the components required by the termination load network is high. Small capacitors and large inductors can be used that exhibit better SRF and Q figures than the low reactance compo-

nents required at the low impedance plane next to the power transistor reducing currents across components, lowering power losses and decreasing the impact of parasitic effects on load impedance synthesis. Figure 3 shows two implementations of an equivalent wideband Class B single end SSPA: A lumped component load network implementation and a mixed load network made of a transformer and a harmonic termination network. The quality factor Q and SRF of their respective components are also shown in Figure 3.

Conventional transformers have been successfully used for years as impedance transformation devices for SSPA load networks from HF to VHF.[8] "Macroscopic" conventional coupled transformers suffer from parasitcs such as leakage inductance. These parasitics limit the maximum operating frequency and bandwidth of the transformer especially in low load impedance planes. Therefore, even thought it is not completely impossible, conventional transformers are rarely used in load networks for SSPAs at UHF and higher frequencies.



	Without transformer version			With 1:3 transformer version		
	Component Value	Q @ 100 MHz	SRF (MHz)	Component Value	Q @ 100 MHz	SRF (MHz)
L1	8 nH	90	5000	8 nH	90	5000
L2	14 nH	110	3400	110 nH	110	1100
L3	8 nH	90	5000	120 nH	120	1300
C1	300 pF	160	400	300 pF	160	400
C2	108 pF	220	500	20 pF	2000	1600
C3	300 pF	160	400	33 pF	1500	1100
R_L	5.5 Ω			50 Ω		

▲ *Fig. 3 Wideband class B amplifier implementations with lumped components only (a) and mixed transformer and lumped components (b).*

Transmission line transformers take advantage of the magnetic and electric coupling properties of transmission lines[7] to improve the performance of conventional transformers at high frequencies. They can be used from HF to mid UHF, but are rarely seen in the microwave region,

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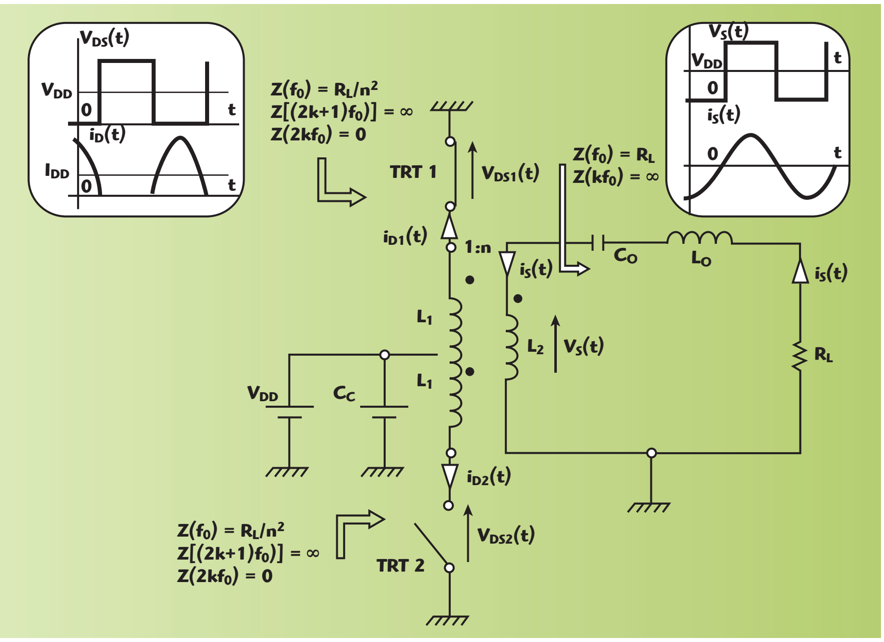
at least based on typical building techniques (using pieces of coaxial cables connected in series or parallel). Nevertheless, conventional (magnetic coupling) and transmission line transformers can also be built in the microwave region using hybrid or MMIC technology.[9]

Besides impedance transformation, other important uses of transformers in SSPAs are the implementation of push-pull amplifier circuits. Push-pull technology can add important practical benefits to SSPA design when it can be used. As a matter of fact, the majority of the most powerful SSPAs in the market are based on push-pull technology.

PUSH-PULL RF AND MICROWAVE SSPAs

In the push-pull topology, two transistors are driven with 180 degrees phase difference and share the same load. Usually transformers are used with push-pull topologies to convert unbalanced loads into the balanced loads required by push-pull amplifiers besides providing impedance transformation functions.



▲ *Fig. 4 Voltage switching class D amplifier schematic, waveforms and load profile.*

Many high power SSPA stages are based on push-pull technology. When very high power levels are involved, push-pull technology is usually the choice for SSPA design. Several technical advantages are attributed to push-pull topology, including direct combination of power delivered by two power transistors operating in phase opposition into one load occupying a small footprint, attenuation of the even harmonics of the ampli-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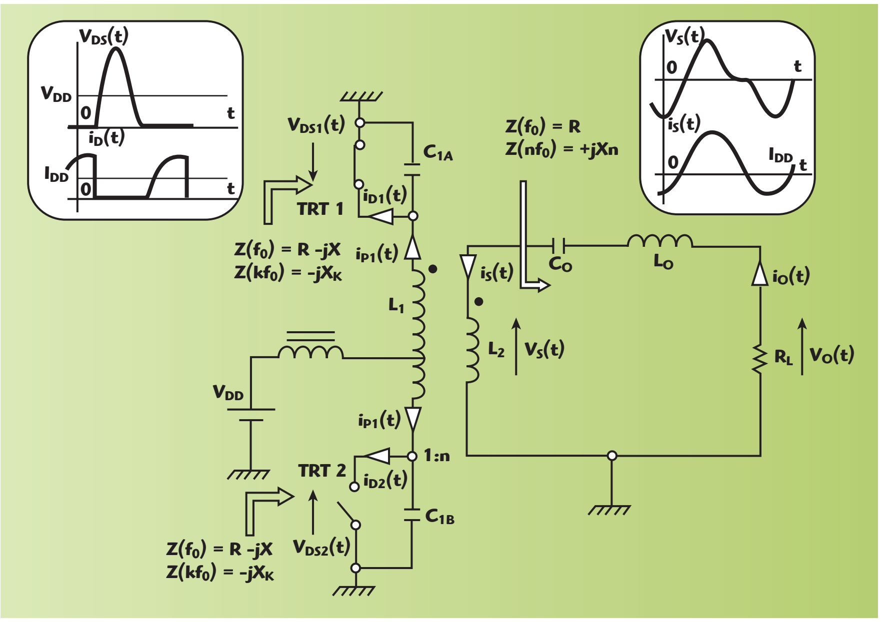
fied signal, load impedance doubling (compared to a single ended amplifier delivering the same power level at the same voltage), etc.

Nevertheless, push-pull topology is not compatible, from a theoretical point of view, with all amplification classes, at least in its direct implementation. Moreover, even amplification classes compatible with push-pull technology exhibit important practical implementation difficulties because some of the parasitics covered previously.

Class B and D (both voltage and current switching) are examples of amplification classes directly compatible with push-pull technology. Push-pull circuits provide an alternated load impedance versus frequency profile (from a non-alternated frequency load impedance) required by Class D. ***Figure 4*** shows this effect on a voltage switching Class D amplifier using ideal switching transistors and a transformer. Voltage and current waveforms and load impedance versus frequency profiles are shown at the primary and secondary of the transformer to point out the harmonic load alternation behaviour associated to the push-pull operation.

Harmonic load impedance alternation versus frequency is essential for some amplification classes such as Class D, but it is not admitted by other amplification classes requiring homogeneous (non-alternated) load impedance profiles at harmonics such as Class E.[3] There are several examples of push-pull Class E amplifiers in the scientific literature, but by analyzing them it is easy to derive that the load is not directly connected across

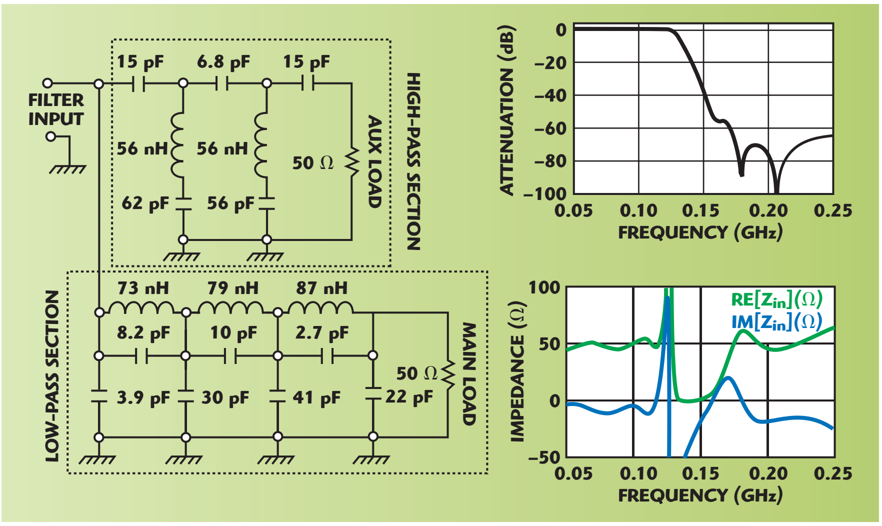


▲ *Fig. 5 Typical push-pull class E amplifier, waveforms and load profile.*

the drains of the two transistors of the amplifier, as happens in push-pull Class B or D amplifiers, but across branches of the circuit where current is sinusoidal. Therefore, in these push-pull designs, two currents of the same amplitude and 180° phase difference are combined, not the non-sinusoidal drain currents inherent to Class E amplification. Obviously, the load profile at the harmonics is not important if only sinusoidal currents are combined.

This is an important difference. In some ways it can be said that these so-called push-amplifiers that combine sinusoidal currents obtained from the branches of two amplifiers driven in 180° phase difference, instead of combining the non-sinusoidal current of the transistors drains, are not pure push-pull designs, but sets of two transistors combined in phase opposition using transformers as combiners. This power combining concept resembles in some way the hybrid combiner[10] without the isolating resistor.

Figure 5 shows a typical Class E push-pull amplifier using ideal switching transistors and a transformer.



▲ *Fig. 6 Diplexer harmonic rejection filter stage for a FM broadcast power amplifier and input impedance vs. frequency.*

Load profiles versus frequency at different impedance planes and voltage and current waveforms are shown too.

There are practical considerations that make difficult the implementation of push-pull topology even using the amplification classes that accept the direct connection of loads across the drains of the transistor pairs such as Class D. Push-pull amplification is also affected by the parasitics of transistors and transformers described previously. For instance, transistor output capacitance has an important impact on the performance of Class D. This reactance is located from the drain to source of each transistor of the push-pull pair, not from drain to drain. The

load profile provided by this parasitic capacitance to the transistors of the push-pull pair from drain to ground is homogeneous (not frequency alternated) degrading the open circuits of the alternated load frequency profile provided by the push-pull circuit. This is one of the reasons the practical implementation of Class D amplifiers at RF and microwave frequencies is difficult. In practice, this capacitance causes many of the so-called Class D amplifiers at high frequencies to not operate in a pure mode, but a mixed mode between Class E and D.

LOW PASS HARMONIC FILTERS

The harmonic attenuation provided by wideband switchmode SSPA load networks, usually designed as bandpass circuits, is not sufficient to fulfil the requirements of modern communication services, demanding harmonic attenuation levels better or equal than 50 dBc.

The more complex the load network of the switchmode power amplifier, the better its harmonic rejection capabilities at the expense of higher power losses. Usually a tradeoff is required for designing the load network of SSPAs in order to balance its harmonic attenuation capabilities and power losses. From a power efficiency point of view, using a low pass harmonic suppression filter after the amplifier load network provides better results than designing a more complex amplifier load network. Nevertheless, care must be taken in this power budget because if the harmonic attenuation provided by the load network itself is not high (20 dB or lower), a low pass filter located at the output of the transistor (among the amplifier and the load) to clean up the output spectrum may change the amplifier performance and even the class of amplification implementation.

Reflective and absorptive filtering technologies can be used to improve the harmonic attenuation performance of power amplifiers. Reflective technology filters "reflect" the energy at the harmonics back to the amplifier. This technology is the most widely used in practical circuits. In theory, the reflected energy at the harmonics by the low pass filter should be converted into energy at the fundamental in the amplifier, but in practice this energy can degrade the amplification class implementation and consequently the amplifier performance. This is because a reflective filter exhibits pure resistive impedance over its pass-band but reactive impedance over its attenuated band, changing the resistive load conditions required by the load network of the amplifier at the harmonics. In practice this effect is only noticed if the harmonic attenuation provided by the load network of the amplifier is not too high (20 dBc or less).

On the other hand, more elaborated absorptive filters, usually based on diplexer technology, provide resistive load impedance to the load network of the amplifier both at the fundamental and harmonics, and consequently do not change the performance achieved by the amplifier without low pass filtering stages. ***Figure 6*** shows a diplexer harmonic filter stage for a FM broadcast power amplifier. It also shows its frequency response and the impedance versus frequency profile provided by this circuit both at the fundamental and harmonics.

CONCLUSION

Many practical considerations, most of them related to the parasitics of transistors and passive components, make the implementation of amplification classes difficult, especially when high power transistors are involved. RF and microwave power transistors usually require very low loads because of the relative low breakdown voltages of currently available solid-state power technologies. Low load impedance conditions amplify the effect of the parasitics and make the implementation of many amplification classes difficult, or degrade or even preclude them, especially in wideband conditions at frequency bands as low as VHF or even high HF.

Mixed load networks for SSPAs made of transformers plus harmonic termination networks are usually more efficient than complicated load impedance transforming networks made of many lumped components or transmission lines. The push-pull topology is an option to consider in order to achieve more powerful amplifiers, but the limits imposed (not by practical considerations but theoretical limits too) must be known because push-pull technology is not compatible with any amplification class.

Low pass filters used to improve harmonic attenuation at the output of the amplifier (especially those based on reflective principles) must also be carefully designed to preserve the resistive load required by the amplifier load network at the fundamental and harmonics. Diplexer technologies must be considered for this function especially in wideband switching amplifiers using wideband load networks that usually does not provide high harmonic rejection (20 dBc or less). ■

ACKNOWLEDGMENTS

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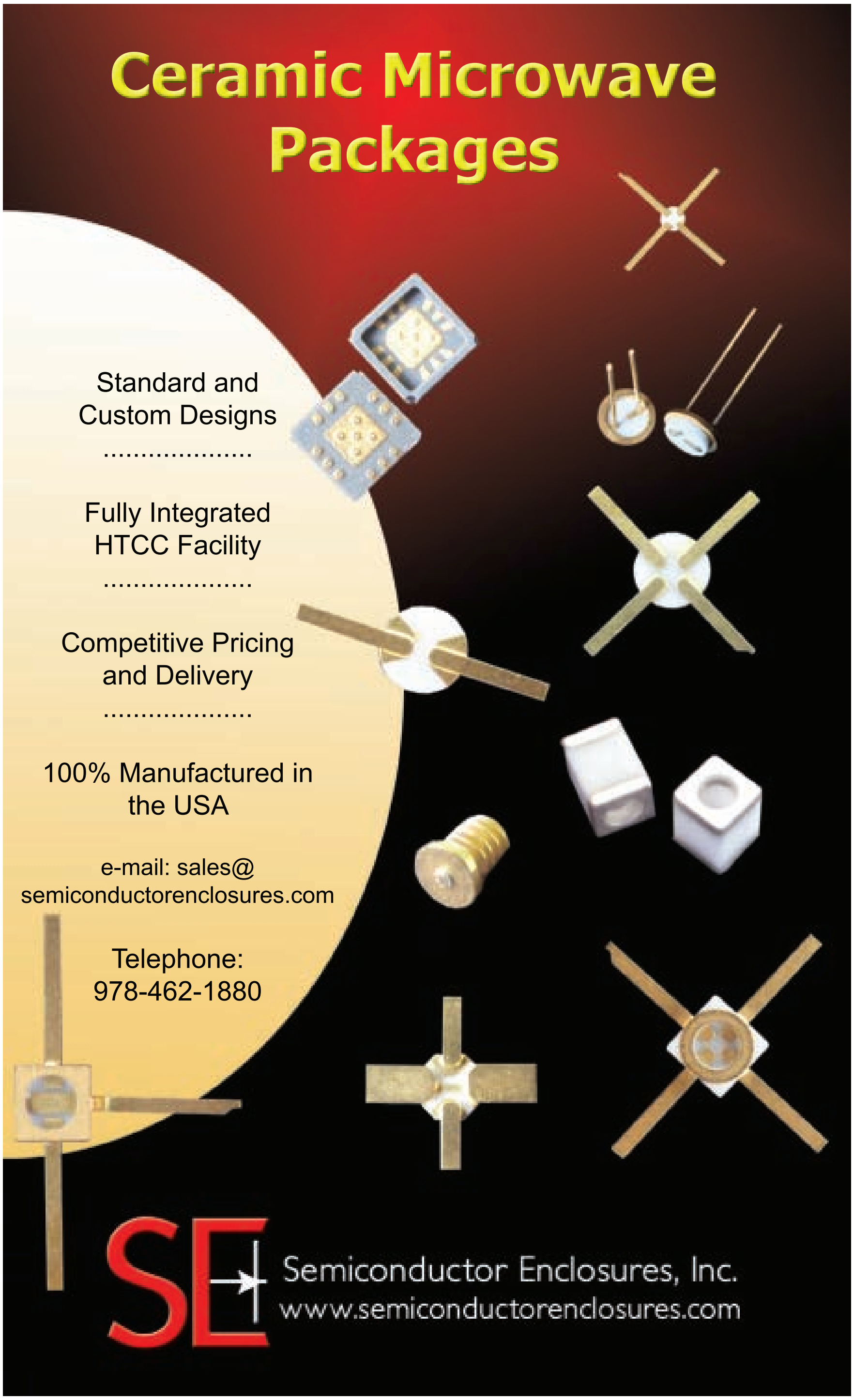

INTEGRATED ASSEMBLIES

The VME Based Receiver SYS1000N01U is a multi-stage superhetrodyne design that will translate an X-band signal with the frequency excursion of 1,000 MHz to an IF center frequency of 70 MHz with an instantaneous bandwidth of 20 MHz. The receiver functionality includes automatic gain control (AGC) attenuator with analog sampling, channel gain balance attenuator, channel phase balance phase shifter, signal injection point, peak detected signals (available via VME interface) and RF signal monitoring points. The receiver is fabricated into a three-slot wide VME module. Control of the receiver components is done using standard VME-64 bus protocol.

VME Receiver

- S, C and X-band dual conversion radar receiver
- Bandwidths up to 1,000 MHz
- Receiver functions:
  - Automatic gain control (AGC) attenuator with analog sampling
  - Channel gain and phase trimmers
  - Peak pulse sampling
  - 3-slot wide VME module
  - Receiver control, BIT and monitoring using VME-64 bus protocol

Switched Output Variable Gain Amplifier

- 11 to 21 GHz frequency range
- +20 dBm output 1 dB compression point
- 30 dB gain
- 4 BIT 15 dB digital gain control
- 4 switched selectable outputs
- High reliability miniature hermetic MIC construction

6-Channel Log Receiver

- 2 to 18 GHz RF bandwidth
- 500 MHz IF bandwidth
- 65 dB log range
- 20 mV/dB log slope
- 2 dB channel-to-channel tracking
- Tangential system sensitivity (TSS) -70 dBm

DIGITAL FEED-FORWARD LINEARIZATION

The intention of this paper is to describe a concept of non-adaptive Digital Feed-forward Linearization, an approach intended to correct unwanted nonlinear effects in power amplifiers. The reason for calling the described approach "digital" is that its corrective signals are generated by means of software, that is in the DSP. The theory of the approach is presented and calculated results are given. Experimental results made with simple arbitrary generated waveforms coincide with predictions.

This paper describes a concept of non-adaptive Digital Feed-forward Linearization. A feed-forward amplifier is a system designed to reduce the spectrum re-grows appearing due to the amplifier's nonlinearity.

There are several general techniques to reduce nonlinearity effects. They are divided into two major groups. One of them (called "predistortion") is geared toward preventing nonlinear effects from appearing. According to this technique, the input signal is distorted in a specific way allowing an output signal to be distortion-free. The second group (called Feed-forward Linearization) focuses on compensation of those effects after their appearance. In that technique the input signal remains unchanged. All the corrections are done to the output signal by adding correcting waveforms in anti-phase to distortions.

Each of the groups has its advantages and disadvantages. Predistortion is cheaper and less cumbersome, but has its physical limitations of the degree of compensation.[1] Feed-forward Linearization has no limitations of compensation in principle, but is more difficult to implement. The implementation of Feed-forward Linearization can be done by either analog or digital means. In analog implementation, distortions are extracted from the output signal (by comparing distorted with undistorted signals) and then added in anti-phase to the output. In digital implementation, the distortions are generated by software means and then, as in the case of analog, are added in anti-phase to the output. The main advantage of digital implementation is in the accuracy of created signals. There is no need to extract distortions from the output signal. Since their nature is known, they are created precisely. The need for adaptation (real-time adjustments based on the degree of distortions) is reduced or eliminated entirely.

In this paper the theory of a spectrum regrowth creation is introduced. Based on it, the scheme for corrections is developed. The traditional analog method of Feed-forward Linearization is given and the advantages of a digital method are shown. One of these advantages is in the knowledge of the nature of sidelobes, which makes it possible to use a non-adaptive compensation. Simulations and experiments are shown to confirm this concept.

BASIC THEORY

Any nonlinear system can be described by the equation:

$$e_{out}=k_1e_{in}+k_2e_{in}^2+k_3e_{in}^3+\ldots \quad (1)$$

where e_{in} is an input signal, e_{out} is an output signal and k_i are complex coefficients.

Modern wireless communications deploy digital data streams as input signals. Their spectrum is represented by the function of the type

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of [sin (x)/(x)].[2] Due to the nature of this function, higher order components spread the spectrum. Additional spreading is happening because of Root Raised Cosine filtering. Only the odd components of Equation 1 add to that spectrum spread.[3] In wireless communications, harmonics are filtered out. The output signal of the nonlinear system for wireless communications is represented by Equation 2:

$$e_{out}=k_1 e_{in}+k_3 e_{in}^3+k_5 e_{in}^5+... \qquad (2)$$

A typical graphical presentation of a data stream spectrum, its cube and its fifth power is shown in ***Figure 1***.

The combination of these waveforms creates the resulting signal according to Equation 2. The reason for sidelobes is the presence of higher order components. In order to eliminate a spectrum spread caused by nonlinearity, it is natural to create higher order waveforms and apply them in anti-phase to the output signal.

ANALOG FEED-FORWARD LINEARIZATION

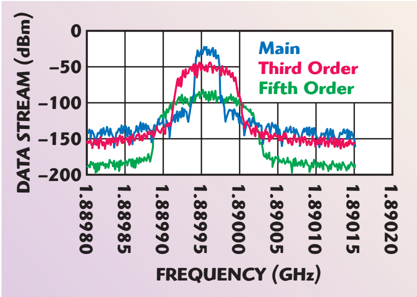
Traditionally, the generation of correcting waveforms (that is, waveforms intended to get rid of nonlinear effects) was done by analog means. The reason for that was in the nature of input signals, which were analog. All the information about distortions was extracted from the output signal, amplified and then added in anti-phase to that same output signal (see ***Figure 2***,[4] where VM is a vector modulator, a device used for adjustments of amplitude and phase of the signal).

The problem with this approach is in accuracy of distortions' extraction. Analog extraction is inaccurate in principle (since it depends on real-time conditions). In addition, RF components used for the extraction are not ideal, so they are enhancing the uncertainty of the extraction.

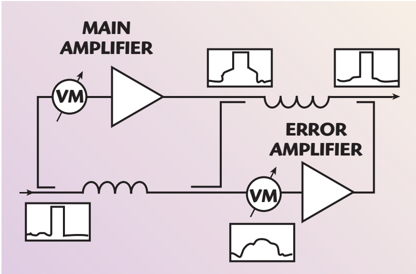
In the systems employing digital data streams as input signals, the accuracy of nonlinear compensation can be significantly increased with simultaneous reduction of the circuitry complexity. Creation of the correcting waveforms by digital means achieves this goal.

DIGITAL FEED-FORWARD LINEARIZATION

Digital Feed-forward Linearization is also intended to correct unwanted nonlinear effects in power amplifiers at its output, only it does so by digital means. It works because of a digital nature of input signals. The waveforms in the systems employing digital data streams are created by means of software, that is in the DSP. In software, it is relatively easy to apply predetermined mathematical functions to those waveforms. Specific mathematical functions required for linearization are the odd powers of the initial signal (that is, its cube, fifth order, etc.). When these functions are applied, the results are to be multiplied to the corresponding coefficients (k_3, k_5, etc.) and added with the opposite sign to the output waveform represented by Equation 2. This will lead to a perfect correction of nonlinearity effects.



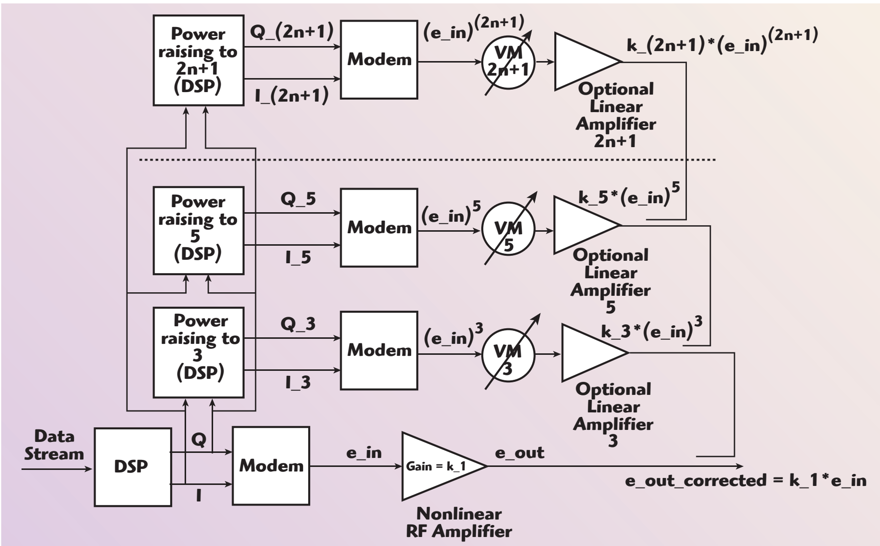
▲ *Fig. 1 Spectrum of a typical data stream (main), its third order and its fifth order.*



▲ *Fig. 2 Traditional feed-forward linearization.*

The signal given by Equation 2, however, is a RF signal (since it represents an output of RF power amplifier). To implement the compensation described above, the functions created in the DSP have to be converted to RF. The multiplication by the corresponding coefficients is also done in RF using vector modulators (similar to Figure 2). Vector modulators maintain the required phase and amplitude plus allow the application of adaptation techniques (if required).

The block diagram depicting this approach is given in ***Figure 3***. This block diagram consists of a number of branches corresponding to the number of powers to which the initial signal is raised. As in every wireless application, the data stream is applied to the DSP, divided to I & Q, conditioned and applied to the modem where it is converted to RF. The unique feature of Digital Feed-forward Linearization is that I & Q are applied not only to the modem, but also used to create additional waveforms. At each of the additional branches, the I & Q are applied as input waveforms, converted to the complex form (with I as real and Q as imaginary), raised to the required power and divided again to their own I & Q conditioned data streams. The newly obtained I & Q are applied to the corresponding modems and the resulting RF signal is applied to the vector modulators for amplitude/phase adjustments. The outputs of



▲ *Fig. 3 Digital feed-forward linearization.*

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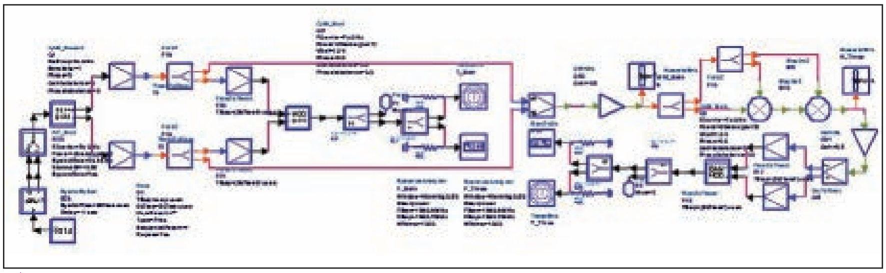
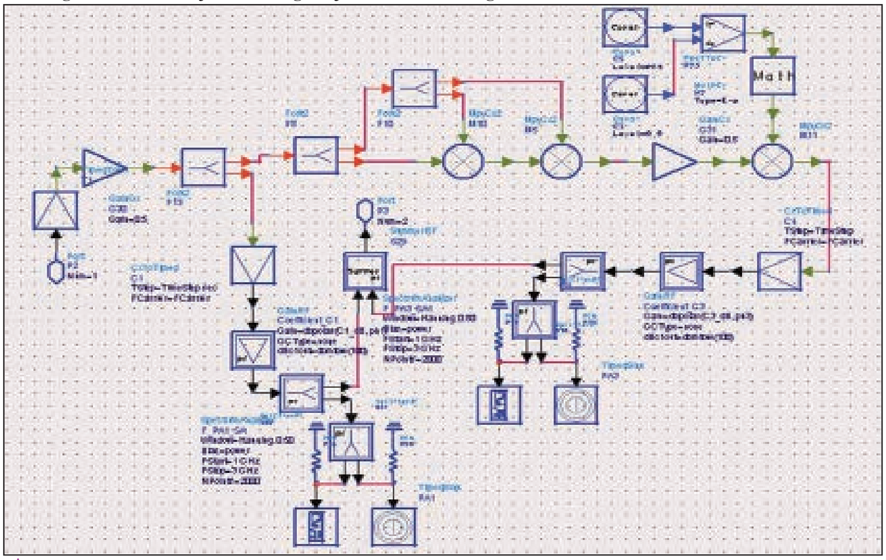


▲ *Fig. 4 Creation of a cube signal from the main signal in a DSP.*



▲ *Fig. 5 Block diagram of the amplifier's behavioral model.*

vector modulators are amplified by linear amplifiers (if necessary; usually, the value of k_3 is about 30 to 40 dB below the value of k_1. This means that in the majority of practical realizations no additional linear amplifiers are needed. However, in the unusual case of a high-gain high-level-of-nonlinearity amplifier, the device similar to the "Error Amplifier" in Figure 2—marked as "Optional Linear Amplifier" on Figure 3—can be added to the system) and added in anti-phase to the output of the nonlinear RF amplifier.

In practical realization, no more than two additional branches are expected, since the influence of higher than fifth-order additions are small. However, as it will be shown later, up to four branches might be required.

It is good to note that in contrary to the previous Feed-forward Linearization schemes,[5,6] the described approach does not necessarily need any adaptive methods. Digital Feed-forward Linearization does not change anything at the input signal; it creates additional signals. By its nature it does not require any adaptation techniques, since all the variations of the power amplifiers' parameters (like frequency, power level and operational temperature) can be predicted and included into control circuitry of vector modulators. However, if prediction of those parameters for any reason is undesirable, adaptation feedback loops for controlling the vector modulators can be included.

ADS SOFTWARE SIMULATIONS

The implementation of the creation of main and cube signals in the DSP (using ADS software from Agilent) is given in ***Figure 4***.

The initial simulation, intended to understand the capabilities of the suggested linearization in principle, was conducted using a custom-made behavioral amplifier model. The main signal was applied to the input of the behavioral amplifier model (see ***Figure 5***) and the cube branch was used for the compensation at the output of the model (see ***Figure 6***). The results, obtained for the source of a WCDMA signal, demonstrating a perfect compensation, are given in ***Figure 7***.

The reason for the perfect compensation is in the chosen composition of the behavioral model, which represents a creation of only up to the

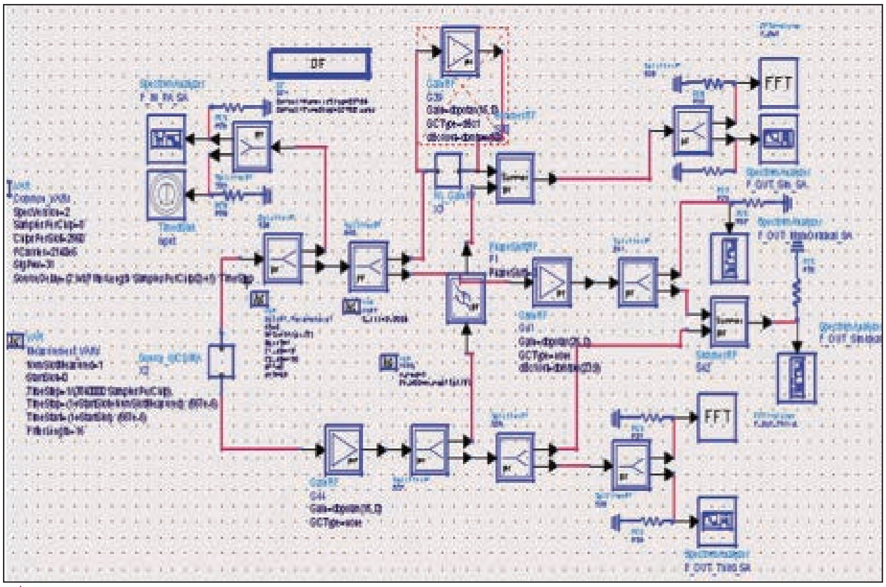


Fig. 6 *Block diagram of digital feed-forward linearization.*

third power of distortions. While the model is fully expandable, it is more convincing to conduct simulations using a model of a real amplifier. For that purpose a model for a 10 W GaN amplifier from NXP Semiconductors was chosen and placed in a matching structure (see ***Figure 8***).

The goal was to substitute the model in the matching structure for the nonlinear amplifier in the block diagram of Digital Feed-forward Linearization, as seen in Figure 6. In order to avoid a co-simulation between ADS's RF and DSP benches, a block diagram similar to the one in Figure 6 (with a source similar to the one on Figure 4, only with five branches instead of two) was assembled in RF bench. In order to speed-up the computation process, instead of the model itself, large-signal S-parameters in p2d format were extracted from the model (see Figure 8) and used for the simulations. To avoid computation complexity, no feedback between output spectrum and correction signals was used, and a required ratio of amplitudes and phases for correction signals was determined manually.

The results are shown in ***Figure 9***. Due to the noisy nature of the waveform's presentation in ADS's RF Bench, the maximum achievable value of ACLR is 51 dBc. This level of compensation is reached with four additional branches of compensating signals (3^{rd}, 5^{th}, 7^{th} and 9^{th} order). When only three additional branches are used, the value of ACLR is 47 dBc, which is good enough for meeting WCDMA requirements. Two branches give the value of ACLR of only 41 dBc, which is also below the limit for the standard.

The given model for a GaN transistor was not checked for its linearity effects, so it is not clear how accurately it predicts the number of required branches for an ideal compensation. However, for the purpose of this paper it is not important. What is important is a demonstration that an ideal level of compensation can be achieved for any given amplifier while using a described approach.

EXPERIMENTAL CONFIRMATION

There is a method for a direct experimental confirmation of a Digital Feed-forward Linearization approach. Rohde & Schwartz offers a Vector Signal Generator (SMU200A), that has two independent RF outputs with synchronized basebands. However, as a substitute, another generator (Agilent 4438B) was employed to confirm the results. This generator has only one output, so the results had to be confirmed indirectly. The method of confirmation has the same idea of compensating waveforms created by digital means, only created waveforms where applied to the amplifier's input (predistortion). For simplicity, only two branches (main and cube) were used in experiment. This method was simulated and the values of amplitude and phase for compensating the

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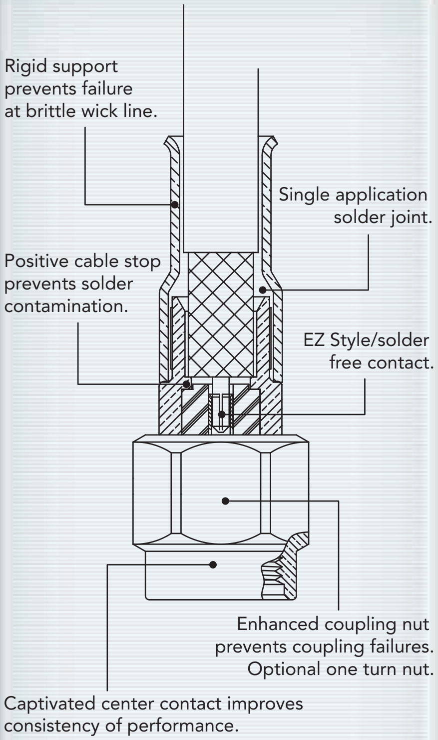

Cable Assembly Performance

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Intermodulation:	< -150 dBc Typ. (2 x 20 watt carriers)
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Temperature Range:	- 40°C to +125°C

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Coupling Nut Retention:	60 lbs axial
Durability:	100 cycles

Connector Materials

Contact:	BeCu, Au/Ni plate
Locking Ring:	BeCu
Coupling Nut:	Stainless steel
Crimp Ferrule:	Soft Cu, Au/Cu plate
Body:	Brass, Au/Cu plate
Insulator:	PTFE
Gasket:	Si Rubber

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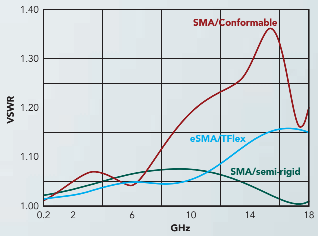

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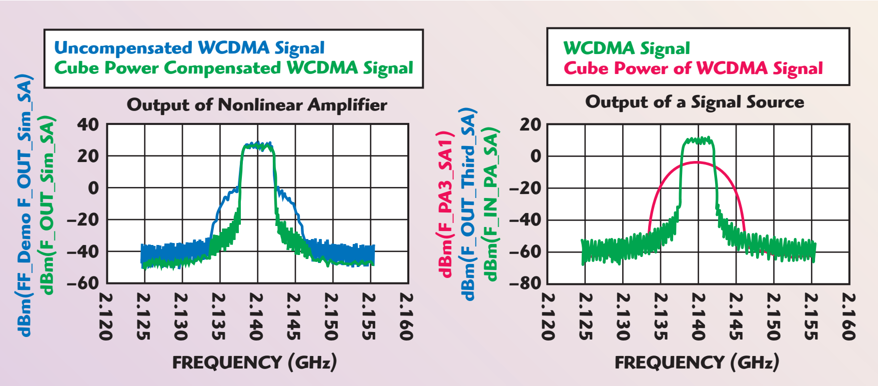
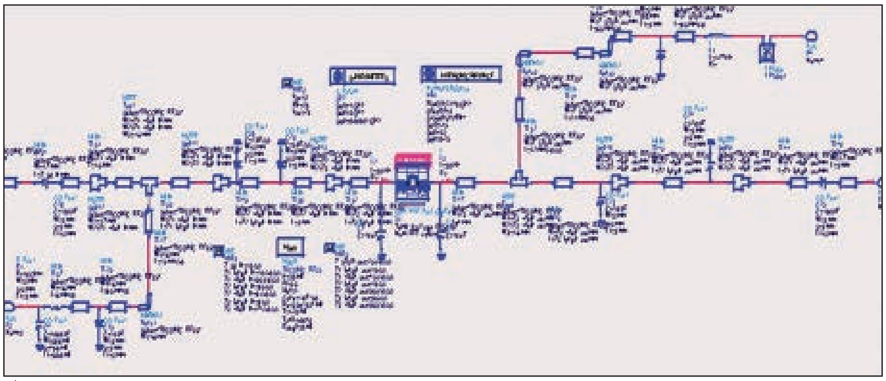
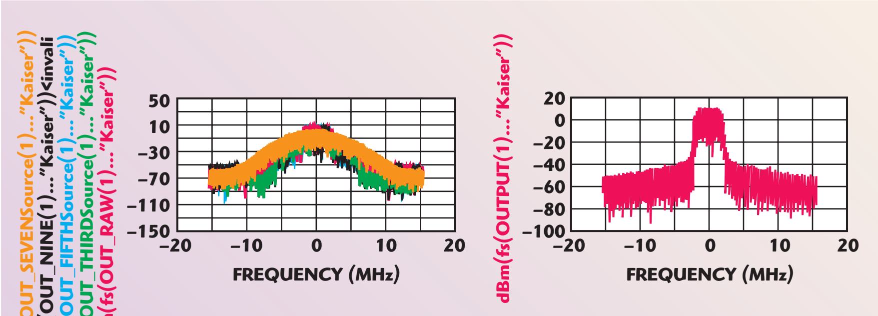


				BW = 3.84 MHz, Spacing = 5 MHz: 2140–5+/–1.92)				
p_out	p_in	Gain	p_inF	p_inCH	p_adj	p_adj_IN	ACPR	ACPR_IN
46.962	30.962	16.000	30.932	30.849	–8.445	–24.444	55.377	55.293

▲ *Fig. 7 Results of simulations on the behavioral model.*



▲ *Fig. 8 Matching structure for a 10 W GaN transistor model.*



ACLR	Pout	Pout_3	Pin	Gain
ACLR (1) –50.984	35.001	29.818	23.614	11.387
ACLR(2) –50.935				

▲ *Fig. 9 Results of simulations on GaN amplifier model.*

cube waveform were found. A block diagram for uploading the waveforms (with a signal source in OFDM format) from ADS to Agilent 4438B is shown in ***Figure 10***.

A generator's output was connected to the input of RFMD amplifier RF2314 and its output spectrum was monitored. Initially the generated cube waveform was attenuated (so only the main waveform appeared at the amplifier's input), and a resulting spectrum was recorded. Then the amplitude and phase of the cube waveform were adjusted according to the predictions of ADS simulation. The sidelobes of the initial spectrum were eliminated, as seen in ***Figure 11***.

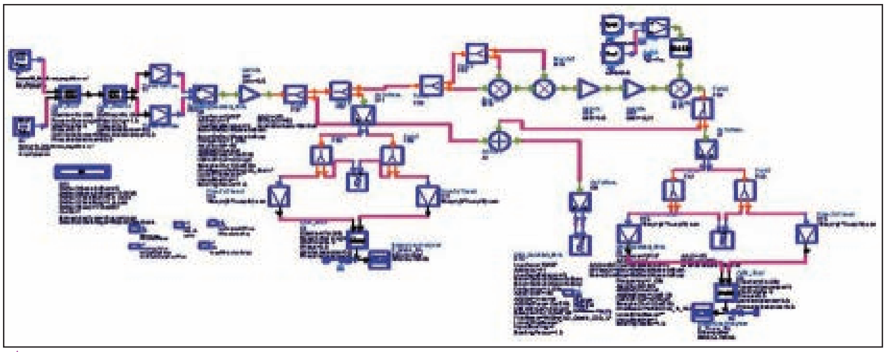


Fig. 10 Block diagram for uploading main and cube signals into Agilent 4438B.

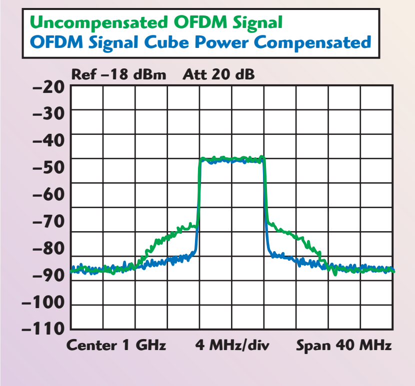


Fig. 11 Experimental results.

CONCLUSION

In this paper a concept of non-adaptive Digital Feed-forward Linearization—an approach intended to correct unwanted nonlinear effects in power amplifiers—is described. It is based on the creation of additional compensating waveforms in the DSP and their conversions to RF. The explanation of the concept was given and supporting simulations were conducted. Experimental results made with simple arbitrary generated waveforms confirm predictions.

The implementation of this concept is relatively simple and all the RF hardware of a traditional feed-forward amplifier is reusable. The only requirement is access to the baseband of the base station, where the feed-forward amplifier is located. When access is gained, the correcting waveforms are generated from the baseband's data stream, converted to RF and applied to the output of the main amplifier. It is expected that in the majority of cases no error amplifiers are going to be needed. The parts count of a feed-forward amplifier is reduced, which reduces the amplifier's cost and improves its reliability.

The described approach to Digital Feed-forward Linearization does not require adaptation techniques. That is, no additional feedback circuitry is needed for the system to work in principle. However, introducing a feedback adaptation would help with keeping near perfect compensation over temperatures, frequencies and power levels. ■

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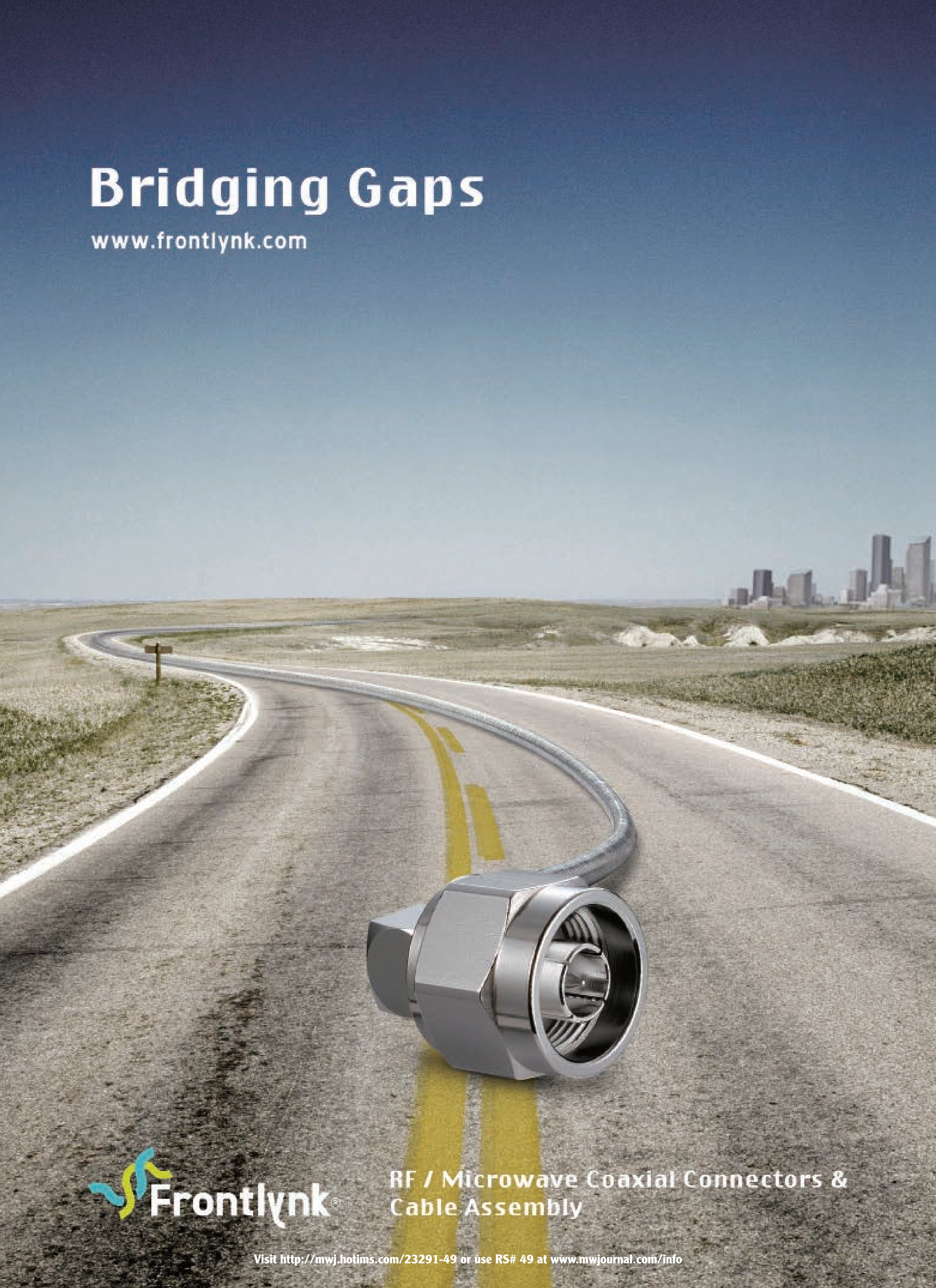
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PHASE NOISE REDUCTION IN MICROWAVE OSCILLATORS

Phase noise is the most important figure of merit of microwave oscillators.[1,2] Although a number of publications have addressed this phenomenon, it still remains one of the most challenging aspects in oscillator design. This article briefly summarizes the research and development effort in the area of low-noise signal generation. It discusses a general noise generation mechanism, the influence of individual elements on phase noise behavior as well as various noise-reduction techniques.

PHASE NOISE PHENOMENON AND MODELING

A typical feedback microwave oscillator, shown in ***Figure 1***, consists of a passive frequency-determining resonant element and an active device required to compensate for the resonator losses in order to start oscillations. The oscillations are initiated due to small, noisy signal fluctuations occurring in the oscillator components. The active device small-signal gain has to be greater than the resonator loss resulting in a rapid increase of the active device output signal. Obviously, some kind of limiting mechanism (such as gain compression) is required to stabilize the output power at a certain level. The gain compression usually occurs in the active device itself due to its natural nonlinear behavior. Thus, at steady state the active device gain becomes equal to the overall loss in the resonator-feedback path that stabilizes the output signal amplitude. The oscillation frequency is determined by the resonator frequency selectivity and phase relationship in the oscillator-feedback path.

Thus, it is important to understand that two essential requirements are necessary to realize an oscillator:

- noisy signal fluctuations in oscillator components are required to initiate oscillations
- a limiting, nonlinear mechanism is required to achieve steady-state oscillations

Unfortunately, these vital features of the microwave oscillator eventually result in output spectrum contamination either directly (that is due to the active device RF noise or resonant-frequency fluctuations) or indirectly (that is due to the up-conversion of the active device low-frequency noise in its nonlinearities). The oscillator noise behavior has been extensively investigated[3-6] and can be represented as follows:

$$\pounds=10\log\cdot\left\{\frac{\mathrm{GFkT}}{2\mathrm{P}}\left[\left(\frac{f_0}{2\mathrm{Q}}\right)^2\times\frac{f_\alpha}{f^3}+\left(\frac{f_0}{2\mathrm{Q}}\right)^2\times\frac{1}{f^2}+\frac{f_\alpha}{f}+1\right]\right\} \quad (1)$$

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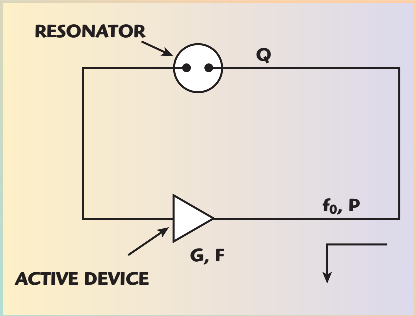
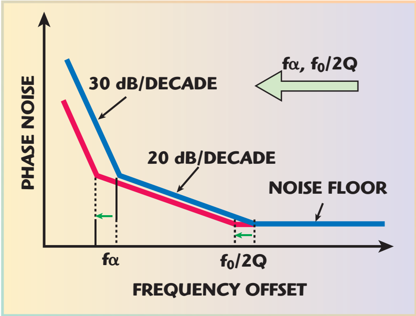
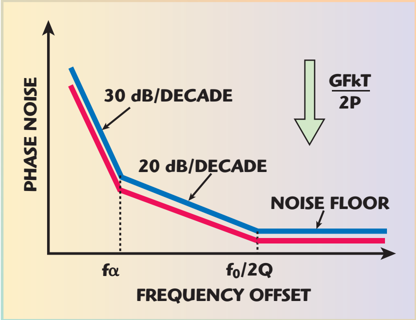


▲ *Fig. 1 Conceptual block diagram of an oscillator.*



▲ *Fig. 2 Phase noise behavior of a microwave oscillator.*



▲ *Fig. 3 Another method for phase noise reduction.*

where:
G = active device gain
F= active device noise factor
k = Boltzman's constant
T = absolute temperature
P = RF power applied to the resonator
Q = resonator loaded Q-factor
f_0 = oscillation frequency
f_α = active device flicker-corner frequency
f = offset frequency

This expression is a well-known modification of Leeson's equation that depicts the oscillator phase-noise behavior in the offset frequency domain. Although the formula defines four basic frequency offset regions, in microwave oscillators the $1/f$ term is usually ignored due to the $1/f^2$ noise domination that leads to the "classical" oscillator phase-noise profile shown in ***Figure 2***. For offset frequencies higher than the resonator half bandwidth $f_0/2Q$, the phase noise is mainly determined by the available RF power level and the active device thermal noise. This region shows a nearly flat response called "noise floor." For frequencies between the half bandwidth and flicker-corner frequency f_α, the phase noise increases at a 20 dB per decade rate. In the last region, where the flicker noise dominates, the phase noise increases at 30 dB per decade. Thus, two important oscillator parameters, namely the resonator half bandwidth $f_0/2Q$ and flicker corner frequency f_α, define the shape of the phase-noise curve, while its magnitude is mainly determined by the $\frac{GFkT}{2P}$ term.

This graph gives a simplified yet very helpful visualization of the phase-noise behavior as well as some intuitive ideas on how to reduce its appearance in the oscillator output spectrum. The phase noise can be controlled by reducing the flicker-corner frequency f_α and/or the resonator half bandwidth $f_0/2Q$ as shown. The flicker-corner frequency is mainly determined by a particular active device and its operating regime, while the half bandwidth is set by the frequency resonator and its coupling scheme. Clearly, utilizing low-flicker-noise devices (such as silicon-bipolar transistors) and applying a high-Q frequency resonator technology are effective and commonly used ways to clean up the oscillator output spectrum.

Alternatively, the entire noise curve can be shifted down, as shown in ***Figure 3***, by increasing the oscillator signal-to-thermal noise ratio. This can be practically achieved by maintaining a higher power level in front of the resonator and/or reducing the active device noise factor, while the active device gain should be set to its optimum value (determined by the resonator coupling as will be discussed below). Thus, extracting a higher power from the active device can provide a considerable effect: the entire phase-noise curve is shifted down, dB for dB. However, the output power increase should be implemented very carefully, since a severe phase-noise degradation can occur because of the active device noise elevation at compression. Thus, the active device should be preferably operated in a small-signal, "linear" regime in order to keep its noise characteristics unaffected. This may sound confusing since in order to get steady-state oscillations, a limiting mechanism is required—that is something has to be nonlinear. However, "something" does not necessarily mean the active device itself. The limiting mechanism can be effectively spread through oscillator components or even moved from the active device to a less critical (from the noise generation point of view) component. In a more general sense, the main idea here is to reduce the influence of oscillator nonlinearities on the phase noise generation process that can be achieved with a variety of linearization and noise suppression techniques.

In summary, the key principles in designing low-noise microwave oscillators are as follows:

- reducing the oscillator half bandwidth frequency by utilizing a high-Q resonator and optimum coupling scheme.
- reducing the flicker-corner frequency by choosing an appropriate active device and its operating regime.
- increasing the oscillator signal-to-thermal noise ratio by choosing an active device with a low noise figure and maintaining high signal level in front of the resonator.
- preventing the active device noise elevation by optimizing the oscillation-limiting mechanism as well as applying active device linearization and noise-reduction techniques.

FREQUENCY RESONATORS

The frequency resonator element has the most considerable impact on oscillator phase-noise and tuning characteristics. Modern microwave oscillators utilize various resonator technologies, based on electromagnetic, electro-acoustic and electro-optical principles.

ELECTROMAGNETIC FIXED-FREQUENCY RESONATORS

An air-filled metal cavity is a typical example of a high-Q electromagnetic resonator, which confines the electromagnetic energy inside a shielded volume.[7] The cavity is usually a cylinder made from a temperature-stable material such as Invar, while its internal walls are plated and thoroughly pol-

ished to minimize the surface resistivity. Since dielectric dissipation and radiation loss are eliminated, the achievable Q is mainly limited by the loss in the metal walls and can be fairly high (10,000-70,000). In spite of the high achievable Q-factors and excellent power handling capabilities, the impractically large size of cavity resonators restricts their application in signal generation.

Smaller sizes are realizable using dielectric resonators. The practical frequency range for the dielectric resonators is between 1 and 40 GHz, while their Q-factor typically reduces linearly with increasing frequency. A Q of 10,000 at 4 GHz is an average representative of commonly used materials.[8-10]

Ceramic resonator oscillators (CRO) offer a low-cost solution for frequencies between a few hundred MHz and a few GHz. The resonator is a silver-plated length of temperature-stable ceramic, shorted on one end; achievable Q-factors are comparable to the dielectric resonator pucks. Their low cost and easy implementation make them an excellent candidate for low-cost CRO modules, which are commercially available up to 8 GHz.[11]

Much higher Q-factors are achievable using sapphire resonators. The resonator is a cylinder made from a single crystal Al_2O_3 material known as sapphire. The material features extremely low dielectric loss at microwave frequencies. The typical Q-factor of a sapphire resonator used in the fundamental $TE_{01\delta}$ mode is 40,000-50,000. The higher-order, so-called "whispering-gallery" modes are utilized to isolate the electromagnetic energy inside the resonator, and therefore reduce the influence of the external elements. Q-factors greater than 200,000 at room temperature have been reported.[12-16]

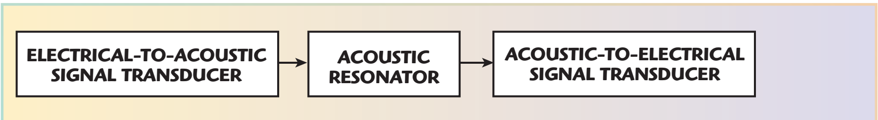
ELECTROMAGNETIC TUNABLE RESONATORS

The main disadvantage of the resonators described above is their limited tuning range, since any resonator detuning adversely affects its Q characteristics. Even frequency locking can be a certain challenge for high-Q resonators such as sapphire. Yttrium iron garnet (YIG) resonators are utilized when wideband tuning and high Q-factors are simultaneously required. The YIG resonator consists of a small (8-20 mils in diameter) sphere placed between the two poles of a cylindrically re-entrant electromagnet and coupled with small wire loops. Frequency tuning is possible since the resonant frequency of the spherical YIG resonator is in direct proportion to the applied magnetic field.[17-23] Thus, the resonant frequency and, consequently, the oscillating frequency can be controlled by changing the DC current injected into the electromagnet tuning coil. YIG resonators offer a relatively high Q (greater than 4,000 at 10 GHz), which linearly increases with frequency. A practical usable frequency range of pure YIG resonators lies between 2 and 50 GHz, similar to the frequency range of dielectric resonators. Lower operating frequencies (a few hundred MHz) are obtainable by adding special dopants (such as gadolinium), although that degrades the Q-characteristics. The highest boundary is mainly limited by magnet saturation and impractically high power consumption, due to the very high current required to generate the necessary magnetic field strength.

Smaller size and lower-cost characteristics are achievable with varactor-tuned oscillators (usually referred to as voltage-controlled oscillators or VCOs), based on either lumped LC or distributed microstrip resonators.[24,25] Frequency tuning is achieved using varactor diodes, since their capacitance depends on the applied tuning voltage. Unfortunately, the Q-factors of these resonators are not high; typical values are between a few tens to a few hundreds, depending on a particular technology and tuning range. Thus, the VCO free-running noise is significantly higher in comparison with YIG-oscillator numbers. Nevertheless, the VCO is an attractive choice in designing a multi-loop PLL synthesizer, since its noise can be suppressed by utilizing a low-noise, fixed-frequency reference oscillator (such as an OCXO) as well as a very wide loop bandwidth. Using a high-quality, single-frequency reference oscillator and a low residual noise, wideband (up to a few MHz) locking mechanism, the VCO-based synthesizers can potentially achieve µsec-fast tuning, together with YIG-like noise performance, without the use of expensive, bulky and power-hungry YIG devices.[26]

ELECTRO-ACOUSTIC RESONATORS

A generic electro-acoustic device combines electrical-to-acoustic and backward acoustic-to-electrical signal transducers with a high-Q acoustic resonator, as shown in ***Figure 4***. A "classical" representative is the crystal resonator, which has demonstrated exceptional high-Q and stability characteristics and has been widely used in low-noise oscillators from low RF through a few hundred MHz. At higher frequencies, surface acoustic wave (SAW) resonators are the most commonly used devices. The SAW



▲ *Fig. 4 Electro-acoustic resonator concept.*

resonator structure is deposited onto a low-acoustic-loss substrate (such as lithium niobate) and exhibits high-Q characteristics at RF and microwave frequencies up to 2 GHz.[27,28] The film bulk acoustic resonator (FBAR) is another representative of the electro-acoustic resonator family. The resonator is a three-layer structure with the top and bottom electrodes of molybdenum sandwiching a middle layer of aluminum nitride.[29] FBARs can be used in the frequency range of a few hundred MHz to approximately 5 GHz, with a typical Q-factor of greater than 500 at 2 GHz.

ELECTRO-OPTICAL RESONATORS

Electro-optical principles are utilized in an elegant optoelectronic oscillator (OEO), which is capable of generating a signal at microwave frequencies.[30] The OEO generic architecture is essentially a transposed gain oscillator that utilizes laser light energy to enable an electro-optical signal conversion. The laser radiation propagates through a modulator and an optical energy storage element (that is a resonator) and then is converted to electrical energy with a photo-detector, as depicted in ***Figure 5***. The electrical signal at the output of the photo detector is amplified, filtered and fed back to the modulator to close the oscillator feedback loop.

The optical resonator is usually constructed using a long fiber delay line; the Q-factor is proportional to the ratio of the delay time and line loss. Since fiber lines exhibit fairly low insertion loss (less than a dB per km), high-Q resonators can be constructed. A loaded Q-factor of 10,000 has been reported using a 2 km fiber line;[31] the longer fibers exhibit even higher Q-factors. Further improvements are possible with a microspherical optical resonator that utilizes multiple reflections inside a fused-silica sphere.[32]

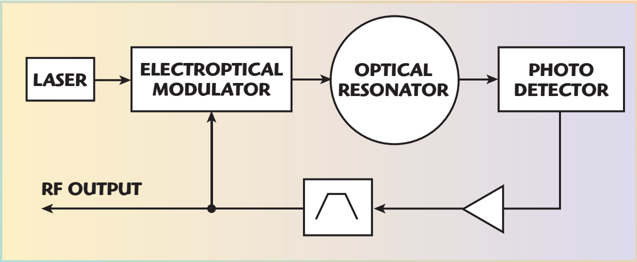


Fig. 5 Opto-electronic oscillator block diagram.

COUPLING

Resonator coupling is another important consideration because any coupling mechanism reduces the residual (unloaded) resonator Q-factor to the actual (loaded) value used in phase-noise calculations. It is a common design mistake to achieve high loaded Q values by using a very loosely coupled resonator. Resonator loss is a function of its unloaded and loaded Q-factors and is given by:

$$L(\mathrm{dB}) = 10\log\left(\frac{1}{1-\frac{Q_L}{Q_U}}\right)^2 \qquad (2)$$

where Q_U and Q_L are the resonator unloaded and loaded Q-factors, respectively.

The undercoupling results in increased overall resonator loss requiring an extra amount of gain to compensate it, which in turn, results in thermal noise increase. Since these two factors work in opposite ways, intuitively, there should be a certain optimum determined by a specific oscillator topology. For example, for the simple feedback oscillator shown previously, the phase-noise minimum is achieved when the resonator loaded Q-factor is set to one half of its unloaded value ($Q_L = 0.5\ Q_U$) that corresponds to a 6 dB resonator loss.[33,34] Other oscillator schemes may require different optimum coupling values due to different design goals and tradeoffs. For example, near optimum results with $Q_L = 0.375\ Q_U$ coupling have been achieved for a more complex frequency-locked oscillator design.[35]

Moreover, the coupling structure does not necessarily have to be symmetrical, that is the two resonator ports may have different coupling coefficients, as required by a particular

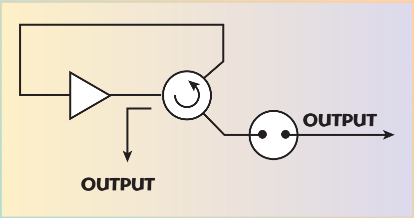


Fig. 6 *Single port arrangement.*

oscillator scheme.[35,36] For example, a circulator-based oscillator, shown conceptually in ***Figure 6***, utilizes a feedback signal reflected from one resonator port only, while the second port is used to extract the output frequency. The output frequency can be also extracted from the amplifier output (or input), thus eliminating the need for a second resonator port at all. No circulator is required in negative resistance designs, which utilize single-port resonators and are commonly used for wideband tunable oscillators.

ACTIVE DEVICES

Although oscillators can be constructed using various devices (such as Gunn or IMPATT diodes), bipolar and field-effect transistors are the most commonly used devices.[10] The transistor gain, maximum oscillation frequency, output power and noise characteristics are the main parameters affecting oscillator design. These parameters are heavily dependent on a particular device; the most common technologies are silicon (Si), gallium arsenide (GaAs) and silicon germanium (SiGe).

Silicon-bipolar-junction transistors have dominated the oscillator field up to approximately 20 GHz due to their excellent 1/*f* noise characteristics. GaAs FET and HEMT devices on the other hand have been demonstrated to oscillate at frequencies beyond 100 GHz as fundamental oscillators. Unfortunately, their flicker-corner frequency is also higher, compared to the silicon-bipolar transistors, which restricts their application in low-noise oscillator designs. In practice, it is more common to achieve millimeter-wave frequencies by using a lower-frequency silicon-bipolar transistor oscillator, followed by a frequency multiplier and bandpass filter. This arrangement usually results in better phase-noise performance, compared to fundamental, GaAs-based oscillators. SiGe is another very promising technology that combines excellent noise characteristics with high oscillation frequencies.

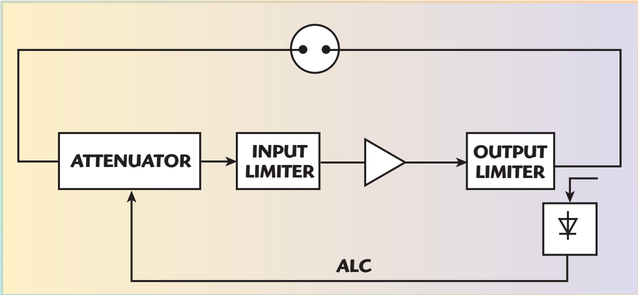


Fig. 7 *Various realizations of limiting mechanisms.*

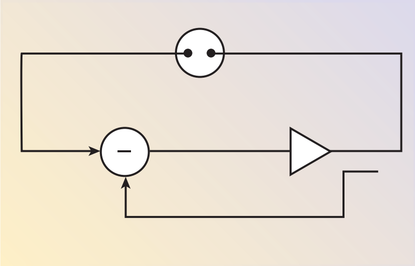


Fig. 8 *RF feedback concept.*

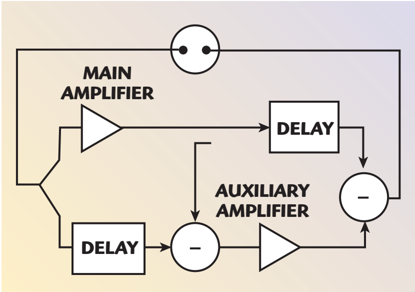


Fig. 9 *Feed-forward concept.*

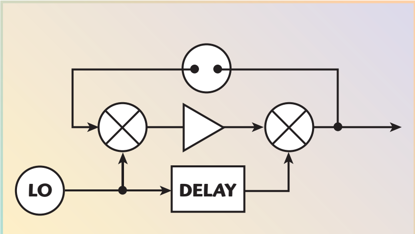


Fig. 10 *Transposed gain oscillator.*

NOISE-REDUCTION TECHNIQUES

Active device linearization is one of the techniques that help in preventing noise elevation. The simplest solution is to avoid or, more exactly, reduce active device compression by implementing another, less noisy limiting mechanism. Various techniques (or their combination) can be used, as shown in ***Figure 7***.

A signal limiter can be placed either before or after the active device, keeping its output well below the compression level. For example, a close-in phase-noise reduction of 15 dB has been observed by adding a diode limiter in an X-band DRO design.[37] The same function can be achieved with an automatic-level-control (ALC) feedback circuit that detects the active device output and adjusts the overall loop gain with an RF attenuator.[27]

The RF signal sampled from the amplifier output can be fed back to, and subtracted from, the RF input signal directly without DC detection, as depicted in ***Figure 8***. This is essentially a generic feedback concept, which can be implemented in a variety of forms ranging from transistor-level local feedback circuits[38,39] to more complex system-level solutions.[40]

Active device characteristics can also be linearized using a feed-forward amplifier approach.[41] The feed-forward amplifier employs two cancellation circuits to generate an error signal and then subtract it from the main amplifier output, as shown in ***Figure 9***. By properly balancing amplitude and phase characteristics, it is possible to remove undesired artifact products created by the main amplifier. This approach is widely used to suppress amplifier intermodulation distortion products; however, it can be effectively utilized for noise reduction as well.[34,40] The level of suppression is mainly limited by amplitude and phase balance; typical values are in the 15 to 40 dB range and can be further improved by applying a more sophisticated balance adjustment.

Another interesting method (shown conceptually in ***Figure 10***) is based on the use of a transposed-gain amplifier.[34,42] This scheme requires a lower frequency active device (compared to the oscillator output frequency) that is achieved by converting the signal in the frequency mixers. Thus, low-flicker-noise silicon-bipolar transistors can be utilized to generate output frequencies greater than their own maximum oscillation frequency. The auxiliary LO noise can be suppressed (to a certain degree, of course) by adjusting the phase delay between the mixer LO ports.

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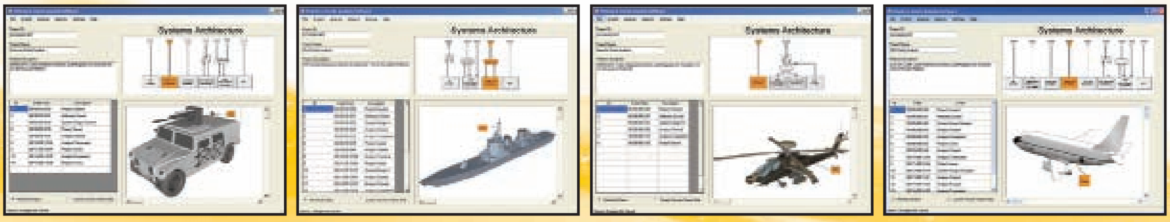

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noise oscillators.[43,46] This approach utilizes a phase detector (usually a balanced mixer) to compare the two signals coming from a VCO directly and through a high-Q resonator used as an external frequency discriminator (see ***Figure 11***). These two signals are adjusted to be in quadrature to increase the phase detector sensitivity. The phase detector produces a voltage that steers the oscillator to suppress its phase-noise fluctuations. The noise suppression is limited by the discriminator sensitivity, which in turn heavily depends on the resonator Q-factor.

Thus, a VCO phase noise can be drastically reduced by utilizing a high-Q external resonator, such as a metal cavity or sapphire. However, this circuit exhibits an initial frequency-lock acquisition problem due to the high-Q resonator characteristics. The problem can be elegantly solved by utilizing a common high-Q resonator, which is simultaneously used as both an oscillator resonant element and frequency discriminator (see ***Figure 12***). A phase noise of -140 dBc/Hz at a 100 kHz offset from a 10 GHz carrier has been achieved using a conventional dielectric resonator with a loaded Q of 1,500 and an FET-based transistor amplifier.[46]

The discriminator sensitivity and consequently the phase-noise performance can be further improved by putting an additional low-noise amplifier (LNA) in front of the phase detector. However, the incident power coming to the LNA should be kept very low to minimize its flicker noise contribution. This can be practically achieved by utilizing a near-critical coupling resonator configuration[47] or an interferometric signal processing.[48,49] A phase noise of -150 dBc/Hz at 1 kHz offset and 9 GHz output has been achieved using a whispering-gallery-mode sapphire resonator and advanced interferometer-based noise suppression circuit.[49]

CONCLUSION

Phase noise remains the most critical specification and design challenge for microwave oscillators. Utilizing low-flicker-noise active devices and high-Q resonators are the most commonly used ways to achieve good phase-noise characteristics. Further improvements are brought on by increasing the output power extracted from the active device and simultaneously optimizing its nonlinear behavior with a variety of linearization and noise-reduction techniques. This

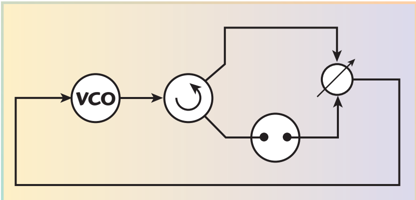

Fig. 11 *Frequency-locked oscillator.*

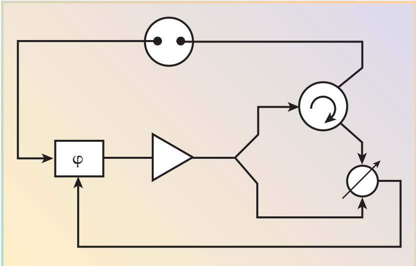

Fig. 12 *Frequency-locked oscillator with a built-in discriminator.*

article has briefly summarized the main methods; further details can be found in the following reference list. Many of the techniques discussed herein are currently implemented at a subsystem-level, using additional parts external to the oscillator itself. Combining and eventually integrating these solutions on a single chip will support the on-going demand for low-cost, high-performance microwave oscillators. ■

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Alexander Chenakin *received his degree from Kiev Polytechnic Institute and has worked in a variety of technical and managerial positions around the world. He has led the development of advanced products for Celeritek, Nextek, Micro Lambda Wireless, General Electronic Devices and other companies. Presently, he is the Director of the Frequency Synthesis Group at Phase Matrix Inc., where he oversees the development of advanced frequency synthesizer products for test and measurement applications.*

Ultra Low Phase Noise 200 MHz to 12 GHz Multiplied Crystal Oscillators

Many demanding applications in the RF and microwave industry require fixed frequency ultra low phase noise frequency sources that provide a high level of performance and reliability. These low noise frequency sources are often comprised of individual quartz-based ovenized crystal oscillators (OCXO) coupled with modular system building blocks such as amplifiers, multipliers, dividers, PLLs and filters that are designed to maintain the low noise integrity of the oscillators and combined to create the desired frequencies and functionality. When required, these components can be integrated into a much smaller footprint to satisfy limited space and weight constraints. These Integrated Microwave Assembly (IMA) products can be custom designed to meet specific needs. Now more standard configurations are also available.

In order to provide fast delivery and excellent performance while minimizing case size, Wenzel Associates has introduced the Multiplied Crystal Oscillator (MXO) Series. This oscillator series of standard integrated assemblies offers world-class performance with the integration of Ultra Low Noise Oscillators and Blue Tops system building blocks in a single machined aluminum case. These ultra low noise sources can be specified at fixed frequencies between 200 MHz and 12 GHz. The versatility offered in the MXO Series products provides quick configuration of previously custom components and makes it an excellent choice for users of high quality frequency sources from VHF to X-band.

CONFIGURATION

There are many ways to create a specific frequency of interest within the MXO oscillator series. Size and performance can be considered in order to optimize the MXO for a specific application at a specific frequency. ***Table 1*** shows some of the more common configurations possible. The circuit configuration and options determine the appropriate case configuration.

There are six cases available: J1, J1P, J2, J2P, J3 and J3P. The "J" and number specify the output stage and the "P" means that a phase lock loop circuit is included. ***Figure 1*** shows the largest case configuration (J3P) and the block diagram for an 8 GHz MXO with the phase locking option added (MXO-8000-J3P). This drawing details the various circuits and stages required to create the 8 GHz MXO and how they are separated and interconnected. Stan-

Wenzel Associates
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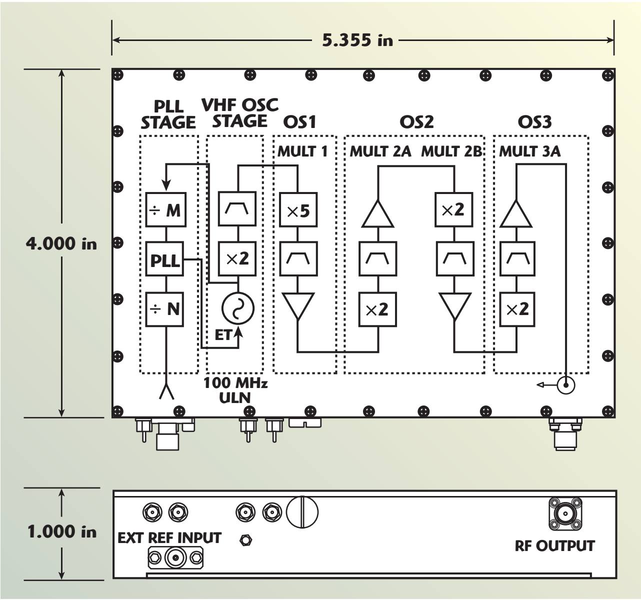
MILLIMETER WAVE RECTANGULAR TE_{10} WAVEGUIDE INFORMATION

WG Band	Waveguide Frequency Range (GHz)	Wavelength Rangeλo (mil)	Wavelength Rangeλo (mm)	Guide Wavelength Range (λg/λo)	Waveguide Impedance Range (Ω)	TE_{10} Cutoff Freq (GHz)	TE_{10} Cutoff λc (mil)	TE_{10} Cutoff λc (mm)	Internal Dimensions (mils)	Internal Dimensions (mm)
WR-28	26.5 - 40.0	445.4 - 295.1	11.313 - 7.495	1.650 - 1.177	621.9 - 443.6	21.1	560.0	14.22	280.0 x 140.0	7.112 x 3.556
WR-22	33.0 - 50.0	357.7 - 236.1	9.085 - 5.996	1.661 - 1.177	626.0 - 443.6	26.3	448.0	11.38	224.0 x 112.0	5.690 x 2.845
WR-19	40.0 - 60.0	295.1 - 196.7	7.495 - 4.997	1.613 - 1.173	608.3 - 442.4	31.4	376.0	9.55	188.0 x 94.0	4.775 x 2.388
WR-15	50.0 - 75.0	236.1 - 157.4	5.996 - 3.997	1.657 - 1.181	624.8 - 445.1	39.9	296.0	7.52	148.0 x 74.0	3.759 x 1.880
WR-12	60.0 - 90.0	196.7 - 131.1	4.997 - 3.331	1.690 - 1.186	637.2 - 447.1	48.4	244.0	6.20	122.0 x 61.0	3.099 x 1.549
WR-10	75.0 - 110.0	157.4 - 107.3	3.997 - 2.725	1.620 - 1.185	610.9 - 446.7	59.0	200.0	5.08	100.0 x 50.0	2.50 x 1.270
WR-08	90.0 - 140.0	131.1 - 84.3	3.331 - 2.141	1.746 - 1.177	658.1 - 443.6	73.8	160.0	4.06	80.0 x 40.0	2.032 x 1.016
WR-06	110.0 - 170.0	107.3 - 69.4	2.725 - 1.763	1.771 - 1.183	667.7 - 445.9	90.8	130.0	3.30	65.0 x 32.5	1.651 x 0.826
WR-05	140.0 - 220.0	84.3 - 53.6	2.141 - 1.363	1.777 - 1.176	669.7 - 443.3	115.7	102.0	2.59	51.0 x 25.5	1.295 x 0.648
WR-04	170.0 - 260.0	69.4 - 45.4	1.763 - 1.153	1.695 - 1.177	638.8 - 443.9	137.2	86.0	2.18	43.0 x 21.5	1.092 x 0.546
WR-03	220.0 - 325.0	53.6 - 36.3	1.363 - 0.922	1.627 - 1.183	613.5 - 445.9	173.6	68.0	1.73	34.0 x 17.0	0.864 x 0.432
WR-02.8	260.0 - 400.0	45.4 - 29.5	1.153 - 0.749	1.708 - 1.177	643.8 - 443.6	210.8	56.0	1.42	28.0 x 14.0	0.711 x 0.356
WR-02.2	325.0 - 500.0	36.3 - 23.6	0.922 - 0.600	1.771 - 1.185	667.7 - 446.7	268.2	44.0	1.12	22.0 x 11.0	0.559 x 0.279
WR-01.9	400.0 - 600.0	29.5 - 19.7	0.749 - 0.500	1.587 - 1.169	598.3 - 440.6	310.6	38.0	0.97	19.0 x 9.5	0.483 x 0.241
WR-01.5	500.0 - 750.0	23.6 - 15.7	0.600 - 0.400	1.620 - 1.175	610.9 - 442.8	393.4	30.0	0.76	15.0 x 7.5	0.381 x 0.191
WR-01.2	600.0 - 900.0	19.7 - 13.1	0.500 - 0.333	1.746 - 1.194	658.1 - 450.1	491.8	24.0	0.61	12.0 x 6.0	0.305 x 0.152
WR-01.0	750.0 - 1100.0	15.7 - 10.7	0.400 - 0.273	1.620 - 1.185	610.9 - 446.7	590.1	20.0	0.51	10.0 x 5.0	0.254 x 0.127



▲ *Fig. 1 8 GHz MXO (MXO-8000-J3P) with integrated PLL.*

dard options include phase locking to an external reference, providing a higher output power level or adding filters for better spectral purity.

Each configuration contains the VHF oscillator stage that includes the ultra low noise oscillator and an optional basic x2 stage. The crystal for this oscillator, provided by the company's Crowen Crystals division, is selected based on the final frequency and multiplier configuration needed.

Output Stage 1 (OS1) adds multiplier 1 and its associated circuitry. This multiplier stage contains the lowest noise odd or even order multipliers available from Wenzel. The final output stage case configuration is J1 or J1P at 2.25 × 4 × 1" or 3.445 × 4 × 1" with phase locking circuitry. This configuration can provide outputs to over 1.2 GHz.

Output Stage 2 (OS2) adds multipliers 2A and 2B to multiplier 1. These stages can also include either odd or even order multipliers that can be installed in either of the two chambers available in this stage. This is the final output stage in case configurations J2 and J2P. The package sizes are 3.205 × 4 × 1" and 4.40 × 4 × 1" with phase locking. Adding Output Stage 2 can provide outputs to over 7 GHz.

Output Stage 3 (OS3) also offers two chambers to house two additional

TABLE I

COMMON MXO CONFIGURATIONS

Frequency Source Only (No PLL) / Part Number	Output Freq.	VHF Oscillator Stage: Oscillator Crystal Freq.	VHF Oscillator Stage: Optional Multiplier x2	Output Stage 1 (OS1): Multiplier 1	Output Stage 1 (OS1): Output 1	Output Stage 2 (OS2): Multiplier 2A	Output Stage 2 (OS2): Multiplier 2B	Output Stage 2 (OS2): Output 2	Output Stage 3 (OS3): Multiplier 3A	Output Stage 3 (OS3): Multiplier 3B	Output Stage 3 (OS3): Output 3
MXO-200-J1	**200 MHz**	100 MHz	—	×2							
MXO-512-J1	**512 MHz**	128 MHz	×2	×2							
MXO-1000-J1	**1 GHz**	100 MHz	×2	×5							
MXO-2560-J3	**2.56 GHz**	80 MHz	×2	×2		×2	×2		×2		
MXO-5120-J3	**5.12 GHz**	80 MHz	×2	×2		×2	×2		×2	×2	
MXO-6000-J2	**6 GHz**	100 MHz	×2	×5		×3	×2				
MXO-8000-J3	**8 GHz**	100 MHz	×2	×5		×2	×2		×2		
MXO-10000-J3	**10 GHz**	100 MHz	—	×5		×5	×2		×2		
MXO-10240-J3	**10.24 GHz**	80 MHz	×2	×4		×2	×2		×2	×2	
MXO-12000-J3	**12 GHz**	100 MHz	×2	×5		×3	×2		×2		

TABLE II

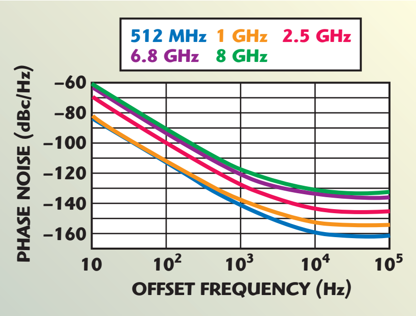
TYPICAL PERFORMANCE SPECIFICATIONS FOR COMMON MXO CONFIGURATIONS

Output Frequency	Typical Phase Noise (dBc/Hz, free-running): 100 Hz	1 kHz	10 kHz	100 kHz	1 MHz	Harmonics	Sub-Harmonics	Spurious
200 MHz	-123	-151	-169	-170	-170	≤ -25 (dBc)	≤ -80 (dBc)	≤ -80 (dBc)
512 MHz	-107	-136	-159	-160	-160	≤ -25 (dBc)	≤ -80 (dBc)	≤ -80 (dBc)
1 GHz	-109	-135	-153	-154	-154	≤ -25 (dBc)	≤ -80 (dBc)	≤ -80 (dBc)
2.56 GHz	-99	-125	-143	-144	-144	≤ -25 (dBc)	≤ -80 (dBc)	≤ -80 (dBc)
5.12 GHz	-93	-118	-136	-137	-137	≤ -25 (dBc)	≤ -80 (dBc)	≤ -80 (dBc)
6 GHz	-92	-117	-135	-136	-136	≤ -25 (dBc)	≤ -80 (dBc)	≤ -80 (dBc)
8 GHz	-89	-114	-131	-133	-133	≤ -25 (dBc)	≤ -80 (dBc)	≤ -80 (dBc)
10 GHz	-87	-112	-130	-131	-131	≤ -25 (dBc)	≤ -80 (dBc)	≤ -80 (dBc)
10.24 GHz	-86	-111	-129	-130	-130	≤ -25 (dBc)	≤ -80 (dBc)	≤ -80 (dBc)
12 GHz	-85	-111	-129	-130	-130	≤ -25 (dBc)	≤ -80 (dBc)	≤ -80 (dBc)

circuits, typically x2 multipliers, and is the final stage for case configurations J3 and J3P. Package size is 4.16 × 4 × 1" and 5.355 × 4 × 1" with phase locking. Output Stage 3 contains multipliers that will generate frequencies up to 12 GHz.

PERFORMANCE

Typical phase noise, harmonics, sub-harmonics and spurious performance for some common MXO configurations are shown in ***Table 2***. An output level of +10 to +13 dBm is fairly standard, but choosing a different amplifier or adding an additional amplifier stage can provide higher output levels. The phase noise performance is the result of Wenzel's industry leading ultra low noise oscillator and the theoretical 20 log(N) degradation of the multipliers plus a few dB of additional intrinsic noise. The multipliers and other circuits following the oscillator are all designed to minimize additive noise, providing the best phase noise possible. Excellent spectral purity is achieved through the use of several strategically located high quality filters. A +15 VDC supply voltage or optionally, +12 VDC, is required to power the oscillator and other circuits, which is internally regulated to minimize power supply noise.



▲ *Fig. 2 MXO measured phase noise plots.*

Figure 2 shows measured phase noise performance for various MXO configurations at 512 MHz, 1, 2.5, 6.8 and 8 GHz. In each case, the crystal frequency was selected to provide excellent close-in phase noise, and the circuits were optimized to achieve ultra low noise floors. Typical noise floor of the 8 GHz MXO is -133 dBc/Hz. With a 1 GHz MXO, the noise floor is better than -154 dBc/Hz.

APPLICATIONS

The MXO Series product line provides high quality signal generation solutions to 12 GHz for some of the most demanding applications in the commercial and defense markets. For example, the MXO can be used as a reference oscillator for phase noise testing by universities and research facilities, as a frequency source generator in a linear accelerator or as a stable high performance source as part of a radio astronomy or telecom system. The compact size, light weight, rugged design and exceptional performance of the MXO make it an excellent frequency source for many military applications such as electronic warfare, ground, mobile and satellite communications, and various radar applications. Low-G performance, MIL-screening and testing to MIL-PRF-55310 can be provided as well.

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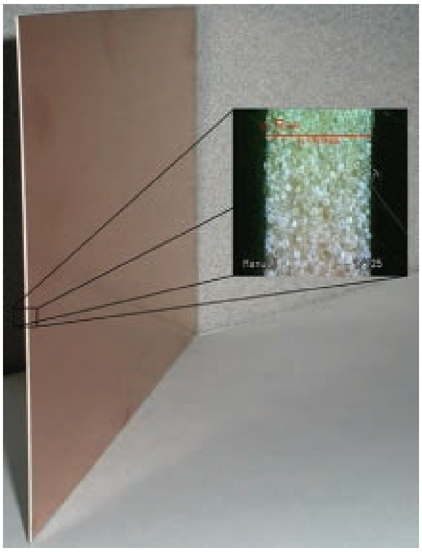
RS No. 302

Low Density Laminate Overcomes PTFE Limitations

Executive Interview Series

MWJ speaks with Jim Carroll, Director of Marketing, Rogers Corp.
Visit www.mwjournal.com to read this in-depth interview.

Circuit weight and density are critical factors in some microwave applications, notably in satellites and airborne systems, including unmanned aerial vehicles (UAV). To meet the needs for high electrical performance with mechanical reliability, Rogers Corp. has developed a new addition to its well-known line of RT/duroid® circuit-board materials: RT/duroid 5880LZ laminate. With extremely low density and a dielectric constant of only 1.96 at 10 GHz, it supports the design of lightweight circuits with excellent thermal stability at microwave and millimeter-wave frequencies.



▲ *Fig. 1 Close-up photo of cross section of the 5880LZ laminate.*

RT/duroid 5880LZ laminate has been formulated to overcome the mechanical and electrical limitations of standard PTFE-based laminate materials. The filled composite material offers the lowest dielectric constant in the industry for a copper-clad PTFE-based laminate, with low density of 1.37 g/cm^3 that makes it suitable for applications requiring lightweight circuit boards. The material uses a unique glass filler system that ensures low density and homogenous electrical characteristics unlike similar materials. ***Figure 1*** shows a cross sectional view of the laminate material.

These laminates maintain their low dielectric constant of 1.96 across a board and from panel to panel with a typical tolerance of ±0.04. That low dielectric constant enables designers to take advantage of thinner circuit boards at higher frequencies without paying a penalty in signal losses. Typically, as the operating frequency of a circuit increases, thinner laminates must be used to avoid unwanted spurious propagation. Unfortunately, thinner laminates dictate the use of narrower conductor widths in order to maintain a controlled impedance (typically 50 Ω). Narrower conductors exhibit higher circuit losses; with thinner laminate materials, the losses of the narrow conductors often dominate a high-frequency design. But by using RT/duroid 5880LZ laminate, microstrip and stripline circuits can be designed for higher frequencies with thinner substrates

ROGERS CORP.
Chandler, AZ

while still achieving controlled circuit impedance by means of thicker-than-standard conductor widths. The end result is lower conductor losses at higher frequencies with RT/duroid 5880LZ laminate.

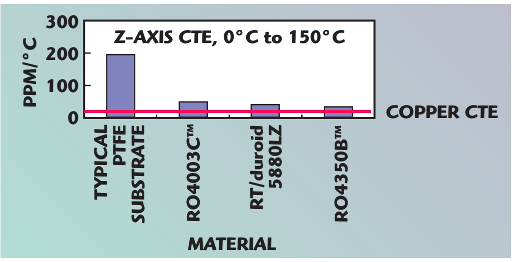
The low dielectric constant of the RT/duroid 5880LZ laminate is beneficial to antenna designers, since the material supports the use of wider conductors at higher frequencies. Since microstrip transmission lines suffer less radiation losses with wider conductors fabricated on low-dielectric-constant materials, antenna efficiency can be increased compared to the use of PTFE-based laminates with higher dielectric-constant values. The RT/duroid 5880LZ laminate exhibits extremely low loss in antenna and other applications, with a typical dissipation factor of 0.0019 at 10 GHz.

THERMAL STABILITY

Although PTFE-based substrates have long been used in critical applications requiring the highest electrical performance, designers have had to overcome limitations with PTFE-based materials in terms of thermal stability. Compared to standard PTFE-based substrates, RT/duroid 5880LZ laminate exhibits very little dimensional instability as a function of changes in temperature (see ***Figure 2***). The RT/duroid 5880LZ laminate even performs well in terms of coefficient of thermal expansion (CTE) performance alongside specially engineered non-PTFE materials from Rogers, such as the RO4350B™ and RO4003C™ laminates. Both are ceramic-filled thermoset materials with somewhat higher dielectric constants (3.48 and 3.38, respectively, reinforced with woven glass for dimensional stability).

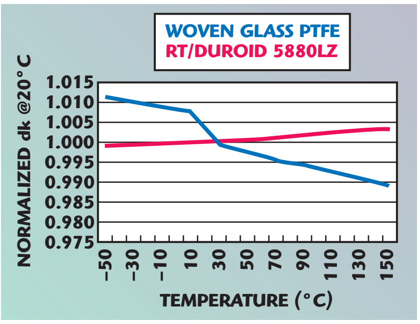
While the typical CTE for a standard PTFE-based substrate is greater than 200 ppm/°C in the material's z-axis, the CTE for RT/duroid 5880LZ laminate is only 42 ppm/°C. This level of dimensional stability over temperature for the RT/duroid 5880LZ laminate material makes it ideal for multilayer circuits in which layers are electrically connected by means of plated through holes (PTH) and excessive expansion and contraction of the circuit boards can result in PTH reliability issues. When using substrates with poor thermal stability, the integrity of PTHs can be compromised when multilayer designs are subjected to thermal cycling during manufacturing test.

In terms of manufacturing, some PTFE substrates with higher CTE values suffer from reliability problems when used in lead-free manufacturing processes. The RT/duroid 5880LZ laminate, with its low CTE, can be routinely processed by means of lead-free manufacturing approaches without concern for reliability.



▲ *Fig. 2 CTE performance comparison of different laminate materials.*

In comparing the thermal characteristics of different circuit-board materials, CTE is often used to evaluate the suitability of a material for multilayer circuit applications. In addition to the physical contraction and expansion with changes in temperature, a substrate's dielectric constant will also vary with temperature, according to a parameter known as the thermal coefficient of dielectric constant. For many materials, this value can be quite high, indicating large changes in dielectric constant as a function with large changes in temperature. For an antenna, for example, a large change from the designed dielectric constant value can result in an unwanted shift in the operating frequency. Typical PTFE-based laminates may exhibit a thermal coefficient of dielectric constant of +150 ppm/°C or higher; the 5880LZ laminate offers a well-controlled thermal coefficient of dielectric constant of +22 ppm/°C. By maintaining stable dielectric constant with temperature, the impedance of the transmission lines and, therefore, the performance of the overall circuit and system, remain stable over variations in temperature. As a comparison, ***Figure 3*** shows the thermal coefficient of dielectric constant for the 5880LZ laminate versus a woven-glass-reinforced PTFE-based substrate.



▲ *Fig. 3 Comparison of the thermal coefficient of dielectric constant for 5880LZ laminate and woven glass PTFE materials.*

Unlike traditional PTFE-based substrate materials, the RT/duroid 5880LZ laminate does not rely on woven-glass reinforcement for dimensional stability but employs a unique filler system to achieve dimensional stability over time and temperature in a low-density substrate material. In some circuit substrate materials, a woven glass structure is used to improve the dimensional stability of the laminate over time and with changes in temperature. Unfortunately, it can also compromise electrical performance at higher frequencies. The glass structure or cloth suffers from inconsistently located glass bundles throughout a substrate panel, as well as areas known as "knuckles" where glass bundles intersect from one axis (x, y, z) in the substrate material to another. The increased amount of glass in these knuckle areas compared to other locations in the glass structure can adversely affect the consistency and repeatability of the dielectric constant across the laminate, impacting the consistency of electrical performance at higher frequencies. The RT/duroid 5880LZ laminate avoids the use of the glass-reinforced layer and its inherent performance issues through the use of a unique filler system.

The high performance and low density RT/duroid 5880LZ laminate makes it ideal for any application where the weight of the printed-circuit board is an issue. The density of the RT/duroid 5880LZ laminate is only 1.37 g/cm^3 compared to the 2.20 g/cm^3 of most typical PTFE-based substrates, making it ideal for use in satellite payloads and in high-frequency airborne circuitry.

***RT/duroid, RO4350B and RO4003C are licensed trademarks of Rogers Corp.*

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RS No. 301

High power, Full-band UHF TV Broadcast Amplifiers

Two new UHF TV amplifiers, one designed specifically for digital service, the other designed for analog service, both with the highest power density currently available, are now offered from Power Module Technology (PMT). The advanced technology incorporated into these amplifiers is also available for microwave applications such as radar, avionics and digital communications. These solid-state pallet amplifiers outperform tube technology providing economies of scale superior to others offered in the market today. Operating cost may be reduced by as much as 30 percent using these new solid-state amplifiers, while providing many years of uninterrupted service.

Power Module Technology has introduced the PP470-860-1000 pallet using LDMOS field effect transistors (FET) provided by NXP. It is designed to deliver the highest RF output power, efficiency and gain available anywhere. Exceptionally rugged, these devices are ideal for use in PMT's broadcast amplifiers providing MTTF/MTBF beyond other products offered in the market today. The PP470-860-1000 is a high power linear Class AB pallet amplifier featuring the latest generation laterally diffused metal oxide semiconductor (LDMOS) transistors, covering the entire UHF TV band. The PP470-860-1000 has 250 W of DVB-T Average Digital Output Power, with shoulder IMDs of less than -33 dBc. ***Figure 1*** shows the gain and efficiency over the operating frequency band (470 to 860 MHz).

Features include:

- 250 W Digital Average Power
- 1000 W Peak Digital Power
- Latest generation LDMOS transistors
- Channel 14-69: 470 to 860 MHz
- 50 ohms input/output
- Thermal tracking bias
- No circuit tuning or RF assembly

A new standard in analog UHF television amplifiers, the PP470-860-600 (see ***Figure 2***) is a high power, full-band (channels 14-69) amplifier designed for analog operation with 600 W of Peak-Sync power across the entire UHF TV band, 470 to 860 MHz. Use of NXP's lat-

POWER MODULE TECHNOLOGY
Carson City, NV

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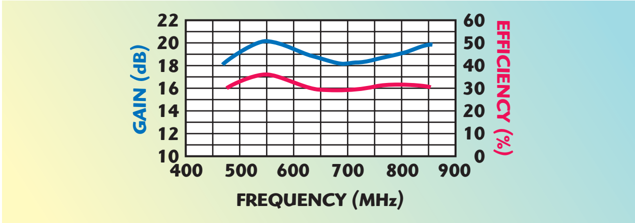
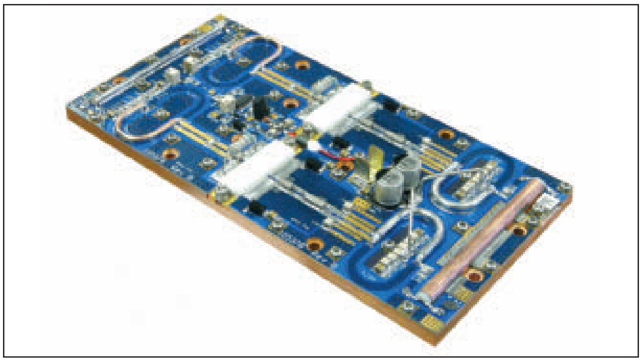


▲ *Fig. 1 PP470-860-1000 gain and efficiency over operating frequency.*



▲ *Fig. 2 Photo of PP470-860-600.*

est generation LDMOS power transistors is key in providing high performance. High efficiency cooling is obtained though the use of a nickel plated copper baseplate and overall amplifier efficiency is typically 40 percent at 600 W Peak-Sync power. Requiring a supply voltage of 40 VDC, a cost-effective telecomm switching power supply can be used, providing high efficiency and high reliability.

The PP470-860-600 can also be used in digital applications supplying 150 W digital average power DVT-B (8K OFDM). Four can be combined for a nominal 500 W of average digital power, or using a back-to-back heatsink, a nominal 1000 W of average digital power.

No circuit tuning is required. With the amplifier fully tested at the factory, the customer simply bolts down the amplifier, connects RF and DC power, and is ready to start transmitting. At 3 $^1/_2$" wide and 1" high, the amplifier is sized for installation with four across a 19-inch rack for a combined 2000 W of Peak-Sync analog output power. Customers can use a back-to-back heatsink for 4000 W of combined analog power.

Power Module Technology is a leader in high power RF amplifier design. Its FM amplifier lineup includes one of the highest power pallet amplifiers at 1500 W CW, currently the highest power density at over 70 W/in^2.

The company's design expertise is being used to expand high power amplifier frequency coverage into the microwave region for CW and pulsed applications using multiple power transistor technologies. High gain, increased efficiency and improved ruggedness are now available in solid-state amplifiers operating as high as S-band. Custom and semi-custom designs are also available. (All of PMT's amplifiers come with a two-year warranty on parts and workmanship.)

Power Module Technology,
Carson City, NV (775) 883-1122, sales@pmtrf.com, www.pmtrf.com.

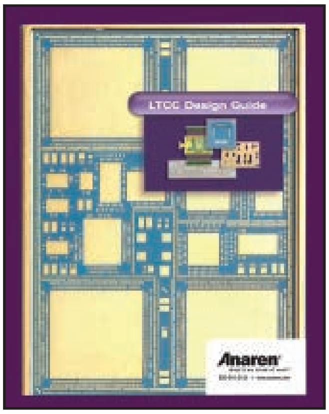
RS No. 300

Application Notes

VENDORVIEW

These free application notes provide insight into solving tough measurement problems in a unique way; in both the manufacturing and design environments. Offering the best combination of speed and scalability, and created and supported by renowned worldwide measurement experts, Agilent's X products help engineers bring innovative, higher-performing products to emerging markets around the globe. Application note topics include femtocell manufacturing, characterizing and designing linear and nonlinear active devices, MIMO receiver test, active device test and testing the DigRF interface.

Agilent Technologies Inc.,
Santa Clara, CA (800) 829-4444, www.agilent.com.
RS No. 310



LTCC Design Guide

This free, low temperature co-fired ceramic (LTCC) design guide offers information useful to any OEM engineer employing LTCC in the design of a new product. The 12-page, illustration and table-rich guide includes information on conductor, via, multilayer and RF/microwave parameters; general design tips and insights of use when laying out LTCC circuits; and introductory information on Anaren's LTCC capabilities, which are offered out of the company's ceramics-focused operation in Salem, NH and augmented by Anaren's RF/microwave engineering expertise at company headquarters in Syracuse, NY.

Anaren Inc.,
East Syracuse, NY (603) 898-2883, www.anaren.com.
RS No. 311

LINC2 Applications CD

ACS has released a new product applications CD for its LINC2 suite of RF and microwave design and simulation software. The CD contains numerous design examples and application notes for creating robust product designs through the efficient use of the LINC2 CAE software package. This interactive menu driven applications CD provides a quick and efficient way to navigate through the topics that are of special interest to the user. New methods for high frequency product design are presented that include the automatic creation of circuit schematics via LINC2 synthesis software. The CD illustrates (through numerous examples and published articles) an efficient design work flow cycle, demonstrating the LINC2 integration.

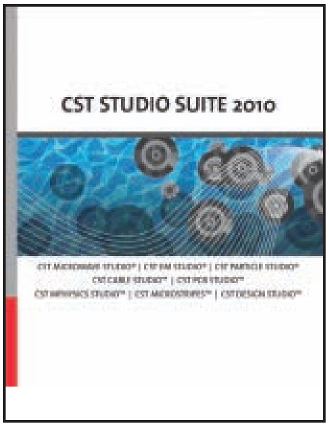
Applied Computational Sciences,
Escondido, CA (760) 612-6988, www.appliedmicrowave.com.
RS No. 312

Microwave Amplifier Brochure

VENDORVIEW

The microwave amplifier brochure from AR RF/Microwave Instrumentation features a wide range of microwave amplifiers. The brochure highlights the "S" series (1 to 800 W, 0.8 to 18 GHz) and TWT amplifier series (1 to 10,000 W, 0.8 to 45 GHz). The brochure includes photographs, descriptions, specifications and performance graphs for each model.

AR RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181, www.ar-worldwide.com.
RS No. 313

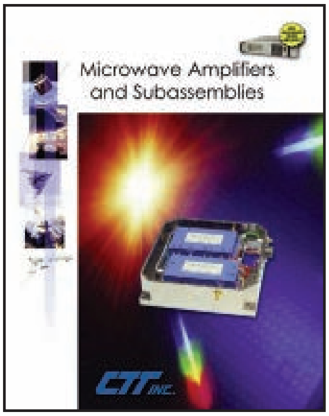


CST STUDIO SUITE Brochure

VENDORVIEW

The new CST STUDIO SUITE™ brochure gives an overview of CST's 3D electromagnetic field simulation solutions available in version 2010. Sections include simulation performance (including acceleration options), workflow integration, and CST's complete technology for 3D EM that focuses on how to choose the right method for your application. CST STUDIO SUITE 2010 includes CST MICROWAVE STUDIO® (CST MWS) with its market leading time domain solver.

CST of America® Inc.,
Framingham, MA (508) 665-4400, www.cst.com.
RS No. 314

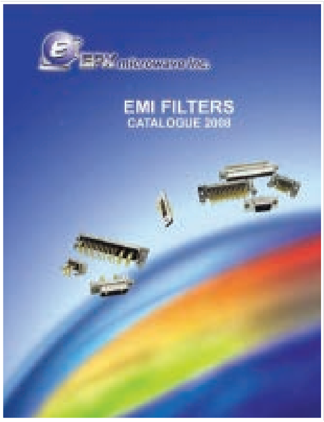


Product Catalog

This updated 36-page catalog features over 145 all-new amplifier products including lightweight and compact 0.5 to 20 GHz LNAs, 0.1 to 20 GHz broadband LNAs, and 0.5 to 31 GHz rack-mount power amplifiers employing GaN and GaAs technologies for UHF through Ka-band applications. CTT's extended product offering includes GaN-based power amplifiers for wideband applications (25 W from 0.5 to 2 GHz), as well as narrowband radar applications (80 W from 8.5 to 9.6 GHz). Additional offerings include high and medium power amplifiers, custom engineered options (CEO) and contract manufacturing services.

CTT Inc.,
Sunnyvale, CA (408) 541-0596, www.cttinc.com.
RS No. 315

EMI Filters Catalog

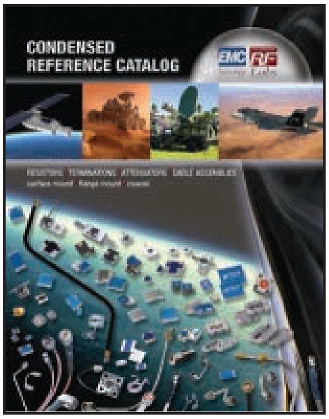


This new catalog presents the company's complete line of EMI filter products. The reference eight-page fold-out lists Combination Filtered Connectors with available 20 and 40 amp high current terminals for work stations, power supplies, switching and transmission equipment; Chip-Cap Filtered Connectors with standard D-subminiature interface (9-37 pins) with options for solder-pin or PCB interconnects either straight or right-angle; High Performance Filtered Connectors (9-37 pins); and Chip-Cap Filter Plates with 12 or 16 positions.

EPX Microwave Inc.,
Santa Clara, CA (408) 313-4913, www.epxmicrowave.com.
RS No. 316

Short Form Catalog

VENDORVIEW



This six-page, short form catalog contains the most up-to-date product and capability offerings from Florida RF Labs/EMC Technology, a Smiths business. The brochure highlights the company's broad product offering that includes RF and microwave resistors, terminations, attenuators (fixed and temperature variable), couplers, power dividers, equalizers and coaxial cable assembly solutions. Component details, data sheets and measured data can all be downloaded from www.rflabs.com and www.emct.com.

Florida RF Labs/EMC Technology,
Stuart, FL (772) 286-9300, www.rflabs.com, www.emct.com.
RS No. 317

Product Literature

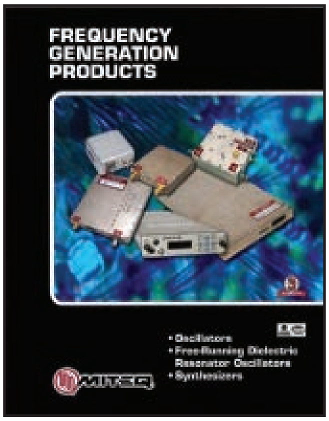
VENDORVIEW

Hittite's October 2009 Off-the-Shelf Newsletter showcases 27 newly released products including several feature articles. Two new product lines are introduced: Synthesizers with Integrated VCOs and Dielectric Resonator Oscillators. Other features include an expanded product 'Applications by Market Table' for products throughout the newsletter. Hittite's 2009 Designer's Guide Catalog is also available on CD-ROM with full product specifications for over 760 products across 22 product lines.

Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343, www.hittite.com.
RS No. 318

Frequency Generation Products Catalog

VENDORVIEW

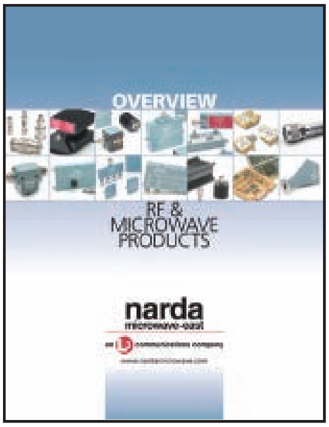


MITEQ's new 80-page Frequency Generation Products Catalog (C-38B) provides detailed information on the company's oscillators, free-running dielectric resonator oscillators and its full line of synthesizers. Included are full electrical specifications, outline drawings, block diagrams as well as typical phase noise charts.

MITEQ Inc.,
Hauppauge, NY (631) 439-9220, www.miteq.com.
RS No. 319

Short Form Catalog

VENDORVIEW



This 12-page catalog covers Narda's broad passive component family, including couplers, power dividers and hybrids, PIN-diode and mechanical switches, attenuators, terminations, and other devices, along with custom components such as high-power dividers, Butler matrices and power sensors. The catalog also describes the company's expanding family of fiber optic modulator drivers for lightwave systems operating up to 100 Gb/s, as well as its RF safety products. A detailed section also illustrates Narda's capabilities in highly-integrated Ultimate MIC and Ultimate SMT multifunction assemblies.

Narda Microwave-East,
Hauppauge, NY (631) 231-1700, www.nardamicrowave.com/east.
RS No. 320

Short Form Catalog

This catalog features the company's RF power products. Power Module Technology Inc. (formerly IMT RF Products Inc.) was founded in March 2005 to design, develop, manufacture and sell broadband pallet/module amplifiers to the FM Radio Broadcast, VHF TV/UHF TV transmitter integrators, military and commercial/industrial communications radio manufacturers in both domestic and foreign markets. Multiple opportunities are being presented to PMT for pallet amplifiers, modular amplifiers, and other special purpose applications by system houses covering the frequency bands from 2 MHz to 3 GHz in power ranges from a few watts to hundreds of watts.

Power Module Technology Inc.,
Carson City, NV (775) 883-1122, www.pmtrf.com.
RS No. 321

Product Selection Guide

VENDORVIEW

Response Microwave Inc. announced the availability of its new product selection guide. The 60-page catalog provides an overview of corporate capabilities and selection tables of the company's passive component and connectivity product offering that operates from DC to 65 GHz, and also selective optical products. It also offers application notes on the company's unique HYBRIDLINE series of drop-in quad hybrids and couplers. The catalog will also be available in a downloadable PDF format at the company website.

Response Microwave Inc.,
Devens, MA (978) 772-3767, www.responsemicrowave.com.

RS No. 322

Product Selection Guide

VENDORVIEW

The RFMD® Multi-Market Product Selection Guide and Aerospace & Defense Product Selection Guide offer broad portfolios of RF components organized in easy-to-scan formats. You will find a listing of products with complete specs or customization information for components designed to fit a wide variety of applications. Download a copy at www.rfmd.com/productguides.

RFMD,
Greensboro, NC (336) 664-1233, www.rfmd.com.

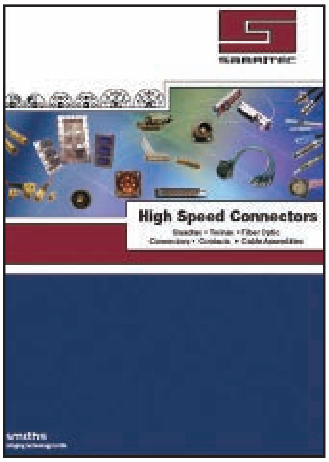
RS No. 323

Precision Microwave Components

RLC, a designer and manufacturer of high quality, state-of-the-art coaxial switches, bandpass filters, precision attenuators and other transmission line components for the microwave industry, announced the arrival of its new catalog. The catalog can be downloaded from the RLC website to your desktop for easy access at www.rlcelectronics.com. This catalog describes RLC's standard product line.

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

RS No. 324

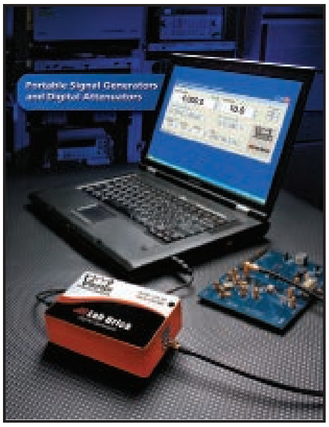


High Speed Catalog

Sabritec, a custom connecting devices manufacturer, announced the release of its new high speed catalog featuring its latest high performance Quadrax, Twinax and Fiber Optic interconnects. The catalog has several new additions including the newly revamped Quadrax reverse gender contacts where the larger heat treated rigid socket contacts are protruding while the smaller pins are supported in the dielectric. These contacts are designed to provide a more reliable and rugged interconnect with better blindmate capability while minimizing the possibility of bent pins.

Sabritec,
Irvine, CA (949) 250-1244, www.sabritec.com.

RS No. 325

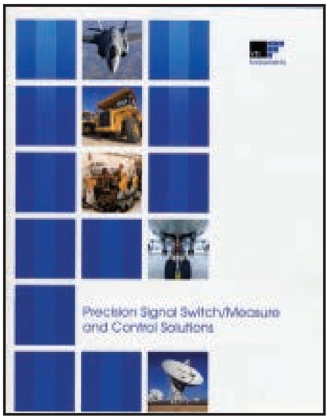


Product Brochure

This six-page "Portable Signal Generators and Digital Attenuators" brochure details features and specifications of the Lab Brick Signal Generator and Lab Brick Digital Attenuator product lines. The brochure presents the five standard signal generator models, LSG-251, LSG-152, LSG-222, LSG-402 and LSG-602. Combined, they cover frequencies from 50 MHz to 6 GHz with high output power levels and excellent spectral purity. Typical electrical and mechanical specifications are presented including phase noise, frequency, output power and spurious.

Vaunix Technology Corp.,
Haverhill, MA (978) 662-7839, www.vaunix.com.

RS No. 326



Product Brochure

VTI's scalable switch/measure and control components have been used at the core of automated test systems around the world. Engineers in the aerospace, defense and avionics industries rely on the company's modular solutions to test their most complex products. This new brochure provides a comprehensive overview of the latest technology available on the LXI, VXI and VME platforms, covering a range of applications from DC to light.

VTI Instruments Corp.,
Irvine, CA (949) 955-1894, www.vtiinstruments.com.

RS No. 327

TAILORED SYSTEMS SOLUTIONS...

For **defense systems** that require:

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- Strong support during system development
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For need ranging from high power to high density. *Flexible* and *semi-rigid* products to withstand the severe conditions of shipboard, airborne or ground-based operations. A low-density PTFE dielectric *reduces attenuation* by up to 30% over conventional materials.

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Radar systems, including phased array. Products and processes optimize *phase tracking* over flexure and temperature. *Miniature* products with *blindmate* connector interfaces such as GPO™ and GPPO™ allow increased packing density.

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Teledyne Storm Products – Microwave
630-754-3300
storm_microwave@teledyne.com

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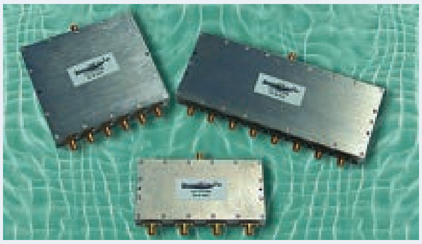
Where “best fit” means more than just offering you the right product, it also means offering the right services and technical expertise to support your unique needs.

WiFi/WiMAX Power Dividers



BroadWave Technologies has expanded its WiFi/WiMAX power divider offering to include four-, six- and eight-way configurations. Model series 151-215-XXX are 50 Ohm, DC to 6 GHz, 1 W units with SMA female connectors. Insertion loss is 1 dB nominal for the four-way configuration across the DC to 6 GHz frequency range. The six- and eight-way configurations' insertion loss is 1 dB nominal DC to 5 GHz and 1.6 dB nominal 5 to 6 GHz. Maximum VSWR for four-, six- and eight-way configurations is 1.50:1. BroadWave also manufactures model 151-173-002, which is a two-way DC to 6 GHz power divider with SMA female connectors. These devices are ideal for dividing signals for in-building wireless, WiFi, WiMAX, Defense, Homeland Security and Public Safety systems. Weather resistant units and other connector types are also available.

BroadWave Technologies Inc.,
Indianapolis, IN (317) 888-8316,
www.broadwavetech.com.

RS No. 216

Cable Assemblies
VENDORVIEW

These LMR® cable assemblies feature low VSWR. Measured performance for a 0.600" diameter, Type N assembly exhibits VSWR that remains below 1.15:1 for a frequency range through 6 GHz. EAM's LMR cable assemblies also offer high power handling capability through 6 GHz, and are available with outside diameters ranging from 0.100" through 0.600". EAM's LMR cable assemblies also exhibit low insertion loss, with typical performance of 11 dB per 100 ft. at 6 GHz for a cable assembly with 0.405" outer diameter. The 50 ohm LMR cable assemblies provide performance comparable to corrugated copper cables, while still offering the flexibility needed to simplify installation. They also exhibit lower loss and superior shielding effectiveness than similar size RG type braided cables.

Electronic Assembly Manufacturing Inc.,
Methuen, MA (978) 374-6840,
www.eamcableassemblies.com.

RS No. 217

Frequency Synthesizer

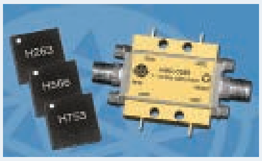
EM Research introduces the UPN-10000, a surface-mount synthesizer operating (fixed or programmable) frequency ranges to 10 GHz with bandwidths up to 30 percent. The synthesizer features an external or (optional) internal reference, and operates over the temperature range of -30° to +70°C (optionally -40° to +85°C). The unit features output power from +7 dBm, low harmonics (<-20 dBc, typical) and low phase noise (<-80 dBc/Hz at 10 kHz, typical – Fout = 10 GHz). The synthesizer operates on a supply voltage at +5 V at 170 mA, typical. Housed in a small surface-mount package (0.9" × 0.9" × 0.15"), the UPN-10000 is ideal for military applications requiring a robust surface-mount design with exceptional performance. The upgraded commercial PN/UPN Series helps to lower overall cost and enhance system performance for CATV infrastructure, optical receivers, fiber optics, and other commercial and military wireless networks.

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

RS No. 218

Wideband Low Noise Amplifiers
VENDORVIEW

The HMC263LP4E and the HMC566LP4E are GaAs PHEMT MMIC low noise amplifiers that are rated from 24 to 36 GHz and 28 to 36 GHz, respectively.



These LNAs have been designed to provide noise figure as low as 2.2 dB with up to 21 dB of small-signal gain, and +24 dBm output IP3 from a single supply of +3/+5 V. The HMC263LP4E and the HMC566LP4E also exhibit high dynamic range and excellent input and output return losses, making them ideal for millimeter-wave system receivers. Ideal for high capacity microwave radios or VSAT applications, the HMC753LP4E is a GaAs HEMT MMIC LNA that operates from 1 to 11 GHz, providing up to 16.5 dB of small-signal gain, 1.5 dB noise figure and output IP3 of +30 dBm.

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

RS No. 219

Directional Coupler

Krytar models 100404010 and 100404020 are directional couplers that operate in a frequency range from 0.4 to 4 GHz. These couplers feature coupling (with respect to output) of 10 ± 0.5 dB, 20 ± 0.8 dB and frequency sensitivity of ± 0.5 dB. The models offer directivity of > 16 dB or > 25 dB, maximum VSWR (any port) of 1.2, insertion loss of < 1.1 dB or < 0.75 dB, maximum power rating (input) of 20 W average, 3 KW peak and SMA female standard connectors. The couplers operate in a temperature range from -54° to +85°C. Delivery: stock to 30 days. Unit may be manufactured to meet military specifications.

Krytar,
Sunnyvale, CA (877) 734-5999,
www.krytar.com.

RS No. 220

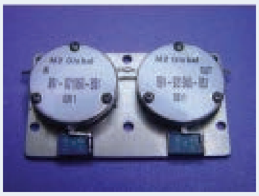
Band Reject Filter

Lorch model 18BRX-1350/X700-NM/N is a band reject filter with specifications of 70 dB from 1200 to 1570 MHz. Insertion loss is 1.2 dB from 20 to 1000 MHz and 1.5 dB from 1800 to 2500 MHz. The VSWR is 1.5:1 over this range also. Power handling is 100 W and package size is 2.5" × 1.0" × 1.0" with an operating temperature of -40° to +65°C.

Lorch Microwave,
Salisbury, MD (410) 860-5100,
www.lorch.com.

RS No. 221

Dual-junction Isolator

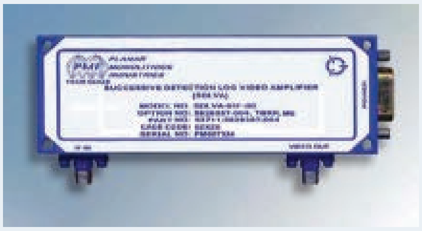


M2 Global Technology Ltd. announces two drop-in isolators for the 921 to 960 MHz and 1805 to 1880 MHz bands. These isolators offer 55 dB isolation over the whole frequency band, allowing OEM manufacturers to specify a single device for double isolation. For both isolators, insertion loss is better than –0.5 dB, and the VSWR is less than 1.14:1 over the operating temperature range of 0° to +85°C. These dual-junction devices are also available in many other frequency ranges.

M2 Global Technology Ltd.,
San Antonio, TX (210) 561-4800,
www.m2global.com.

RS No. 222

Successive Detection Log Video Amplifier



Model SDLVA-61F-80-5829387-004 Options TBRK, MS is a matched set of successive detection log video amplifiers (SDLVA) in a compact stacked configuration. This unit operates over 61.25 MHz ± 250 KHz with a transfer function of E – 22.5 P_{IN}+ 200, where PIN is the input power in dB above -80 dBm and E = output voltage in millivolts. The unit has been designed so that both modules share a common power terminal.

Planar Monolithics Industries Inc.,
Frederick, MD (301) 631-1579,
www.planarmonolithics.com.

RS No. 223


Mini-Circuits
MCA1
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Components

40 GHz Attenuator

Aeroflex/Inmet releases the next generation of 40 GHz, 2.92 mm attenuators with extended power handling capability of a minimum of 2 W average power. The new offering compliments the current 0.5 W attenuator family providing an excellent cost-to-performance ratio. Designed for use in both the test and measurement market as well as OEM systems, these high quality attenuators offer an alternative to other "scientific grade" products on the market. Standard dB values include 3, 6, 10, 20 and 30 dB while many non-standard designs are available on request.

Aeroflex/Inmet Inc., Ann Arbor, MI (734) 426-5553, www.aeroflex.com/inmet.

RS No. 224

Cavity Bandpass Filter

VENDORVIEW

The model AB2436B480 is a ruggedized, weatherproof cavity bandpass filter for outdoor IEEE-802.11b/g WiFi installations that offers excellent harmonic rejection, handles up to 50 W of RF input power and is extremely selective. The eight section cavity bandpass filter has a center frequency of 2436.5 MHz, 3 dB bandwidth of 70 MHz, typical insertion loss of 0.9 dB, return loss of 18 dB minimum, harmonic rejection greater than 80 dB and handles 50 W of RF input power. The AB2436B480 has an operating temperature range of -40° to +85°C and measures 4.8" × 2.8" × 1.2".

Anatech Electronics, Garfield, NJ (201) 772-4242, www.anatechelectronics.com.

RS No. 225

Quick-Fit Connectors

The SMART Quick-Fit compact connectors for 7/8" corrugated cables follow the proven SQF design. New features include one-piece assembly and extended compatibility with all important cables on the market. There is back compatibility with old cables and the ability to fit the latest 7/8" low attenuation cables. There are also aluminum versions and features to make life easier for customers regarding logistics and the final job of feeder cable termination.

HUBER+SUHNER AG, Herisau, Switzerland +41 71 353 41 11, www.hubersuhner.com.

RS No. 226

50 W Loads

VENDORVIEW

MECA offers medium power, 50 ohm loads efficiently designed for high performance, cost-effective solutions. Rated for 15 W average power (2 kW peak) with VSWR of 1:10:1 to 2 GHz, 1.20:1 to 6 GHz and 1.30:1 to 12 GHz. Available from stock in Type-N, SMA, BNC and TNC connector styles (male/female). Made in the USA with a 36-month warranty.

MECA Electronics Inc., Denville, NJ (866) 444-6322, www.e-meca.com.

RS No. 227

Power Splitter/Combiner

VENDORVIEW

The ZAPD-2DC+ two-way power splitter/combiner offers excellent RF performance in a small package. The DC pass through feeds DC on the coaxial center conductor from Port 1 to the Sum to support remote amplifier power. Built in a rugged shielded case, the ZAPD-2DC+ is available with three connector options: BNC, SMA and

N-Type. This power splitter/combiner offers L-band coverage in a frequency range from 950 to 2150 MHz and low insertion loss of 0.25 dB typical. The ZAPD-2DC+ is well suited for tower-mounted amplifiers, GPS and satellite distribution or any other application where a high performance splitter with DC pass through is required.
Mini-Circuits,
Brooklyn, NY (718) 934-4500,
www.minicircuits.com.

RS No. 228

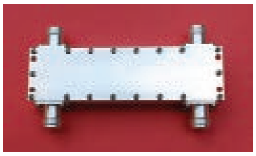
Tunable Cavity Filters

NIC introduces its tunable cavity filters designed for TACAN/DME ground receivers. Extremely low insertion loss is obtained using silver plated coaxial cavity and the tuning screw is self-locked using Posi-Torque Bushing, which ensures precise and stable frequency tuning. Single and multi-pole designs are available depending on the rejection requirement. Custom designs are available. Features include: Precise and stable frequency tuning; low insertion loss; and narrow bandwidth.
Networks International Corp.,
Overland Park, KS (913) 685-3400,
www.nickc.com.

RS No. 229

High Power Hybrid

VENDORVIEW

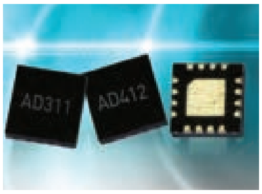


Response Microwave announced the availability of its new application specific 3 dB, 90° quadrature hybrid for use in high-power telecom distribution applications. The new unit operates between 800 to 2400 MHz. Electrical performance offers typical insertion loss of 0.3 dB, isolation of 23 dB minimum, VSWR of 1.22:1 maximum and coupling of 3±0.5 dB. Average power handling is 200 W. Unit is available with type N female connectors standard and alternate interfaces available upon request. The package size is 5.6" × 1.54" × 1.02", plus connectors.
Response Microwave Inc.,
Devens, MA (508) 231-8787,
www.responsemicrowave.com.

RS No. 230

Active Divider

VENDORVIEW



RFHIC Corp. released three- and four-way active dividers for Digital TV and Set top box applications. AD311 is a low cost SMD type three-way active divider for LCD TV, PDP TV, CATV Set top box, or GE-PON applications. Most of the TV system and set top box systems for CATV, Cable modem, Digital TV, Analog TV applications that use multiple tuners will need RF power splitters to divide the RF signal efficiently before the tuner. AD311 covers 45 to 1000 MHz, with 8 dB gain, and offers good gain flatness and noise figure, great VSWR and linearity.
RFHIC Corp.,
Suwon, Korea 82-31-250-5011,
www.rfhic.com.

RS No. 231

Coaxial to Waveguide Adapters

RLC Electronics now offers coaxial to waveguide adapters in a variety of configurations for your specific application. Option A is broadband adapters that offer excellent electrical specs and are maintained over the entire adapter bandwidth. Option B offers enhanced performance over a specific band of the adapters' bandwidth. Computer design and the latest in RF techniques coupled with precision assembly ensure optimal electrical performance in the recommended frequency ranges.
RLC Electronics Inc.,
Mount Kisco, NY (914) 241-1334,
www.rlcelectronics.com.

RS No. 232

2010 INTERNATIONAL MICROWAVE SYMPOSIUM

IEEE MTT-S • MAY 23-28, 2010 • ANAHEIM, CALIFORNIA

THE GOLDEN STATE OF MICROWAVES

IMS2010 FINAL CALL FOR PAPERS

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chairman@ims2010.org

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Interactive Forum
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Panel Sessions
Mike DeLisio
delisio@ieee.org

Focused/Special Sessions
John Horton
j.horton@ieee.org

Student Paper Competition
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studentpapercontest@ims2010.org

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Exhibition Management
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c.jackson@ieee.org

The IEEE Microwave Theory & Techniques Society (MTT-S) International Microwave Symposium for 2010 (IMS2010) will be held in Anaheim, California, as the centerpiece of Microwave Week 2010, scheduled from Sunday, May 23 through Friday, May 28, 2010. **IMS2010 offers technical paper sessions, workshops/tutorials, poster sessions (called open forum), applications seminars (called MicroApps), plenary and panel sessions, industrial exhibits, historical exhibits, and a host of other activities including a guest program for the spouses and accompanying family members. The Microwave Week comprises still other activities, including the RFIC Symposium, and the ARFTG conference collocated with IMS2010.**

REQUEST **Authors are invited to submit technical papers describing original research, development, and application work on radio-frequency and microwave theory and techniques, in the various areas within this field; on the following page is a list of areas that is only suggestive and not intended to exclude other areas.**

INVITATION TO PAPERS IN EMERGING TECHNICAL AREAS **The Technical Program Committee of IMS2010 would like to emphasize in the strongest possible terms that the scope of the 2010 International Microwave Symposium is not limited to the 31 topical areas listed below in this Call for Papers. The Committee is taking deliberate steps to broaden the horizon of the Symposium by including technical areas that, although within the field of interest of IEEE MTT-Society, have not historically had, or do not currently have, adequate representation in the program of the symposium. We enthusiastically invite submission of papers that report results of progress in the state-of-the-art of technological areas that are outside the scope of the listed topics, or are new to the Symposium. Illustrative examples of these areas include:**

- **RF components for very low-cost, high-volume manufacturing in applications like RFID**
- **Terahertz technology and chips for bio-assays**
- **High-power components and techniques for heating and industrial processing**
- **DSP techniques for enhancing specifications of RF circuits and RF techniques for enhancing specifications of DSP hardware**

Because these areas will include newly emerging technologies or breakthroughs, an a-priori list of these areas can not be anticipated.

All papers submitted to IMS must be reviewed by one of the subcommittees of the IMS Technical Paper Review Committee (TPRC) assembled for each respective area (including those for the 31 areas listed below). In order to accommodate the review of submitted papers in new areas, additional subcommittees of the TPRC will be created essentially in real time, as the need for them becomes apparent from the received paper submissions. The need for new TPRC Subcommittees may arise either when the submitted papers lie outside the domain of any existing TPRC subcommittee, or there is a sizable cluster of papers in a subset of the domain of a subcommittee that justifies its own TPRC subcommittee, or to nurture a budding area within the Symposium.

Authors who believe their papers fall in any of those categories are asked to select "Emerging Technologies" as the topic during the paper submission.

PAPER SUBMISSION INSTRUCTIONS **Technical papers to be considered for presentation at IMS2010 must be submitted electronically, in pdf format, via the symposium webportal, www.ims2010.org. This website provides complete information on submission procedure, registration, and related items. Paper or printed copies of submissions cannot be accepted. Symposium proceedings are published as a CD ROM by IEEE, and posted in their digital library. Authors of high-quality papers will be invited to submit an extended version of their paper for the Special IMS2010 issue of IEEE Trans. Microwave Theory & Techniques.**

PROPOSAL INVITATION **The Technical Program Committee (TPC) of the Symposium also invites proposals for:**

- **Workshops (ranging from expert-level to tutorials and short courses), and**
- **Special Sessions (including focused, honorary, and panel/rump sessions).**

Details regarding the types of workshops sought, information requested along with the proposal, and the proposal evaluation criteria, are available on the Symposium website www.ims2010.org. Special sessions on topics that are currently being intensely pursued, contentious, or relevant to the theme of the Symposium or to the microwave community in Southern California, may be proposed for consideration by the Technical Program Committee of the Symposium. For full consideration, all proposals should be received by the posted dates.

TECHNICAL AREAS

Microwave Field and Circuit Techniques

1. Field Analysis and Guided Waves
Novel guiding structures, new physical phenomena in transmission lines and other wave guiding structures and new analytical methods for solving guided-wave problems.

2. Frequency-Domain EM Analysis Techniques
Frequency-Domain methods for numerical solution ofelectromagnetic problems, including field interactions with devices, circuits and with other phsyical processes.

3. Time-Domain EM Analysis Techniques
Time-Domain methods for numerical modeling of high frequency electronics, including modeling based on physical behaviors (electromagnetic, semiconductor, thermal, mechanical).

4. CAD Algorithms and Techniques
Circuit analysis methods, optimization methods, statistical analysis.

5. Linear Device Modeling
Linear models of active and passive devices, models.

6. Nonlinear Device Modeling
Large-signal device models, characterization, parameter extraction, validation.

7. Nonlinear Circuit and System Simulation
Harmonic balance, simulation techniques, distortion and spurious analysis, system simulations and behavioral modeling.

Passive RF and Microwave Components

8. Transmission Line Elements
Planar, non-planar and micro machined transmission lines and waveguides, including periodic and metamaterial-type structures, discontinuities, junctions and transitions.

9. Passive Circuit Elements
Couplers, dividers/combiners, hybrids, resonators, lumped element approaches to circuit design.

10. Planar Passive Filters and Multiplexers
Innovative synthesis and analysis of planar filters and multiplexers, including planar superconducting structures.

11. Non-planar Passive Filters and Multiplexers
Waveguide, dielectric resonator and non-planar super conducting structures.

12. Active, Tunable, and Integrated Filters
Integrated filters (on Si, LTCC, LCP, MCM-D, GaAs,...) active, tunable and reconfigurable filters. Filters based on metamaterials, DGS, EBG and other structures.

13. Ferroelectric, Ferrite, and Acoustic Wave Components
Ferroelectric devices, bulk and thin film ferrite components, surface and bulk acoustic wave devices including FBAR devices.

14. MEMS Components and Technologies
RF micro electromechanical and micro machined components and subsystems: switches, resonators, tunable passive filters, phase shifters, reconfigurable filters and antennas. Modeling, packaging, reliability, novel materials and assembly processes.

Active RF and Microwave Components

15. Semiconductor Devices and Monolithic ICs
Multifunction and monolithic integrated components: RF, microwave and millimeter-wave MMICs on GaAs, SiGe ICs and other technologies. MMIC manufacturing, reliability, failure analysis, yield and cost.

16. Signal Generation
CW and pulsed oscillators, VCOs, DROs, YTOs, PLOs and frequency synthesizers. Applications of new devices and resonators, noise in oscillators, DDS techniques.

17. Frequency Conversion and Control
Electronic switches, phase shifters, limiters, mixers, frequency multipliers and frequency dividers.

18. HF/VHF/UHF Technologies and Applications
Technology for HF, VHF and UHF including passive and active components, lumped and distributed elements, transmitters and receivers.

19. Power Amplifier Devices and Circuits
Design and performance of discrete and IC power amplifiers for RF, microwave and millimeter-wave signals, wide bandgap devices.

20. High-Power Amplifiers
High-power amplifier design and characterization, linearization techniques, power combining techniques, vacuum electronics.

21. Low-Noise Components and Receivers
Low-noise amplifiers, detectors, devices, receivers, radiometers, models and characterization methods for low-noise circuits and components.

22. Millimeter-Wave and THz Components and Technologies
Millimeter-Wave components, technologies and applications above 30 GHz, sub millimeter wave/terahertz devices, instruments and applications including THz imaging.

RF and Microwave Systems and Applications

23. Microwave Photonics
Microwave/optical interactions and device technology. Wireless over fiber, free-space optical technology, broadband cable applications of photonics, optical transmissions effects.

24. Signal Processing Circuits at GHz speeds
High-speed mixed-signal components, modules and subsystems: ADC, DAC and DDS; backplanes, signal integrity and equalization, electrical/optical interfaces and transmission; MIMO; SDR and coherent systems.

25. Packaging, Interconnects, MCMs and Integration
Dielectrics and substrates, component and subsystem packaging, assembly methods, hybrid integration, interconnects and multi-chip modules (MCMs), hybrid manufacturing, yield and cost.

26. Instrumentation and Measurement Techniques
Network, time-domain and spectral measurements, field mapping, error correction and estimation, materials measurements.

27. Biological Effects and Medical Applications
Biomedical applications of microwaves, applications in biology, microwave fields and interactions in tissues.

28. RF Arrays as Antennas and Power Combiners
Smart antennas for wireless applications, spatial power combining, phased arrays, retrodirective systems, T/R modules, multi-beam scanning, active integrated antennas.

29. Radar and Broadband Communication Systems
Broadband and MMW communications systems for terrestrial, vehicular, satellite and indoor applications. Radar systems and subsystems UWB systems and subsystems.

30. Wireless and Cellular Communication Systems
Wireless system and transceiver architectures for 3G/4G for cellular system, WLAN, UWB, WiMax and Cognitive Radio Systems.

31. Sensors and Sensor Systems
RFID, IVHS, wireless micro sensors, nondestructive testing, imaging and remote sensing.

Emerging Technologies

32. New technologies and applications with significant recent advancements

TECHNICAL PAPER SUBMMISSION PROCESS

In order to be considered by the Technical Program Committee for presentation at IMS2010, all technical papers must be submitted prior to the deadline, in a summary form (the final manuscript will be requested only after paper selection for accepted papers).

INSTRUCTIONS FOR SUBMISSION

1. Download the paper submission template from www.ims2010.org to view the suggested manuscript format; authors are urged to adhere to the format and template provided. aAll submissions must be in English. The paper summary must be in pdf format and the file size must not exceed 1 MB.

2. Submit the papers at the webportal www.ims2010.org by November 30, 2009 (local time). Late papers will not be considered. The system will not accept manuscripts exceeding a total of four pages (including the text, figures, tables, references, etc.)

3. Authors of submitted papers will be required to submit a final paper for publication in the Symposium CD ROM. Notice of acceptance, and instructions for the submission of the final manuscript will be sent to authors of accepted papers in January 2010.

CLEARANCES

It is the authors' responsibility to obtain all required company and government clearances prior to submitting a paper. A statement certifying that such clearance has been obtained, and a completed IEEE copyright transfer form, must accompany the final manuscript of each accepted paper. Details regarding the clearance are available from the symposium website www.ims2010.org.

PAPER SELECTION CRITERIA

All submitted technical paper summaries will be reviewed by the IMS2010 Technical Program Committee (TPC), using the following criteria:

1. ***Originality.*** **How is the contribution significant and innovative, and how does it advance the state-of-the-art? Is previous work by the author(s) and others cited?**

2. ***Content.*** **Does the paper include quantitative details? Does it provide explicit description and supporting data?**

3. ***Clarity.*** **Does the paper clarify its contribution and places it in the context of earlier works? Are the writing and the accompanying figures clear and understandable?**

4. ***Relevance.*** **Is the paper of interest to the membership of the IEEE MTT-S and the attendees of this symposium?**

TECHNICAL AREA SELECTION

The author must select a technical area, from the list of technical areas listed here and in the symposium website, which best describes the contribution of the paper in the judgment of the authors; this author-selected area will be used to determine the appropriate review committee for the paper. Choose a primary and an alternate area when you complete the author registration form; these can be selected from different groups in which the 31 areas are classified. The IMS2010 TPC reserves the right to direct the papers to a more suitable area in case of inappropriate selection of area by the author.

PRESENTATION FORMATS

Accepted papers can be scheduled for presentation at the Symposium in three different formats:

1. Regular papers, orally delivered from a podium with electronic projection, which permits a limited audience interaction; this format is suitable for significant contributions and formal presentation.

2. Short papers, also presented orally with very limited audience interaction, suited for reporting refinements or improvements in established technologies in a limited time.

3. Interactive Forum Papers, presented in a poster format, with opportunity for display of hardware, demonstration of performance, and allowing informal extended discussions withinterested individuals among the attendees.

While the author's preference as to the format will be considered, the paper will be placed in a session, and a presentation format, as recommended by the reviewing Technical Program Committee, consistent with the constraints of the Technical Program.

NOTIFICATION

Authors will be notified of the decision of the Technical Program Committee in January 2010, via e-mail, using the address provided during the author registration and submission of the paper summary. Authors of accepted papers will be referred to the Symposium webportal for forms and detailed instructions on preparation of the manuscript for publication in the Symposium CD ROM. Final manuscripts must be received by March 4, 2010, to be published in CD ROM, and to qualify for presentation at the symposium.

STUDENT PAPER COMPETITION

A student paper competition will be held as part of the Symposium. Student papers will be reviewed in the same manner as all other conference papers. To be considered for the competition, the lead author of the paper must be a full-time student (enrolled for at least 9 hours/term for a graduate student or 12 hours/term for an undergraduate) during the time the work was performed, and the paper must be presented by the student author. During the paper submission process, the student submitting the paper is required to provide an e-mail address of the advisor, who will then be asked to certify that the work is primarily that of the student. Papers accepted for the competition will be judged for content and presentation, and awarded first, second and third prizes.

2010 INTERNATIONAL MICROWAVE SYMPOSIUM

IEEE MTT-S • MAY 23-28, 2010 • ANAHEIM, CALIFORNIA

THE GOLDEN STATE OF MICROWAVES

Anaheim, CA
May 23–28, 2010

Microwave Field and Circuit Techniques

1. Field Analysis and Guided Waves
2. Frequency-Domain EM Analysis Techniques
3. Time-Domain EM Analysis Techniques
4. CAD Algorithms and Techniques
5. Linear Device Modeling
6. Nonlinear Device Modeling
7. Nonlinear Circuit and System Simulation

Passive RF and Microwave Components

8. Transmission Line Elements
9. Passive Circuit Elements
10. Planar Passive Filters and Multiplexers
11. Non-planar Passive Filters and Multiplexers
12. Active, Tunable, and Integrated Filters
13. Ferroelectric, Ferrite, and Acoustic Wave Components
14. MEMS Components and Technologies

Active RF and Microwave Components

15. Semiconductor Devices and Monolithic ICs
16. Signal Generation
17. Frequency Conversion and Control
18. HF/VHF/UHF Technologies and Applications
19. Power Amplifier Devices and Circuits
20. High-Power Amplifiers
21. Low-Noise Components and Receivers
22. mm-Wave and THz Components and Technologies

RF and Microwave Systems and Applications

23. Microwave Photonics
24. Signal Processing Circuits and GHz speeds
25. Packaging, Interconnects, MCMs and Integration
26. Instrumentation and Measurement Techniques
27. Biological Effects and Medical Applications
28. RF Arrays as Antennas and Power Combiners
29. Radar and Broadband Communication Systems
30. Wireless and Cellular Communication Systems
31. Sensors and Sensor Systems

Emerging Technologies

32. New technologies and applications with significant recent advancements

SUBMISSION DEADLINES

Special Session Proposals
**Friday
August 28, 2009**

Workshop
**Posted at www.ims2010.org
Friday
October 16, 2009**

Technical Paper
Electronic Submission **Monday November 30, 2009**

Notification of Acceptance **Monday January 18, 2010**

Final Manuscript for Accepted Papers **Thursday March 4, 2010**

Final Manuscript of Workshop Notes **Thursday March 11, 2010**

2010 IEEE Radio Frequency Integrated Circuits Symposium
Anaheim, California
May 23-25, 2010

IEEE

IMS2010 ANAHEIM CALIFORNIA

RFIC 2010 Call for Papers

The **2010 IEEE Radio Frequency Integrated Circuits Symposium (RFIC 2010**) will be held in Anaheim, California on May 23-25, 2010. For the latest information, visit: **www.rfic2010.org**

Electronic Paper Submission/Communication: Technical papers must be submitted via the RFIC 2010 web site at **www.rfic2010.org.** Hard copies will not be accepted. Complete information on how and when to submit a paper will be posted on the RFIC 2010 web site.

Technical Areas: Papers are solicited describing original work in RFIC design, system engineering, system simulation, design methodology, RFIC circuits, fabrication, testing and packaging to support RF applications in areas such as, but not limited to:

- **Cellular System IC's and Architectures:** GMSK/8PSK, CDMA, 3/4 G, Wi-MAX, GPS.
- **Wireless Data System IC's and Architectures:** Bluetooth, 802.1x, Telemetry, RFID.
- **Wide Band System IC's:** UWB, MMDS, CATV, Optical System, Backplane.
- **Small-Signal Circuits:** LNA's, Mixer's, VGA's, Active Filters, Modulators.
- **Large-Signal Circuits:** Power Amplifiers, Drivers, Advanced TX circuits, Linearization.
- **Frequency Generation Circuits:** VCO's, PLL's, Synthesizers.
- **RFIC Device Technologies:** IC Technologies, Si, MEMs, SOI, GaAs.
- **RFIC Testing:** Packaging, Modules, Embedded Testing.
- **Modeling and CAD:** RFIC Modeling, Characterization of Active and Passive Devices.
- **Si Millimeter Wave IC's:** Circuits (PA, Mixer, LNA) and Systems (Vehicular, Medical).

Technical Format: The technical sessions will be held for three days from Sunday through Tuesday. Workshops will be on Sunday. Several invited sessions and talks will take place during the conference.

Microwave Week 2010: The RFIC 2010 will be in conjunction with the IEEE MTT-S International Microwave Symposium (IMS). Microwave Week 2010 will continue with the International Microwave Symposium and Exhibition, and the Microwave Historical Exhibit.

Guest Program: The renovated Anaheim Convention Center and Anaheim Hilton has completely transformed our 2010 conference location since we were there in 1999. The surrounding area has also been significantly upgraded to appeal to both young and old alike. The new Disney's California Adventure® Park offers many more entertainment options. And the recently completed Garden Walk brings vast dining options in addition to Downtown Disney and the surrounding establishments.

Electronic Submission Deadlines

Technical Paper Summaries in PDF format:	**5 January 2010**
Final Manuscripts for the Digest and CD-ROM:	**2 March 2010**
All submissions must be made through the RFIC2010 portal:	**www.rfic2010.org**
ALL SUBMISSIONS MUST BE IN PDF FORM	**Hard copies not accepted**

MTTS

Sponsored by the IEEE MTT-S, EDS, and SSCS
http://www.rfic2010.org

SSCS EDS

Amplifiers

GaN Amplifier

Aethercomm model SSPA 0.869-0960-56 is a high power, Gallium Nitride (GaN) amplifier that operates from 869 to 960 MHz minimum and is packaged in a compact, high performance package. This amplifier is designed for operation in harsh environments. Typical output power is 50 W across the band at P3dB. Small-signal gain is 55 to 56 dB across the band typically. Power added efficiency in saturation is typically 40 to 50 percent across the band. Input and output VSWR is 2.0:1 maximum. This unit is equipped with DC switching circuitry that enables and disables the RF devices inside the amplifier in 2000 nSec typical for turn on and 5000 nSec typical for turn off time.

Aethercomm Inc., Carlsbad, CA (760) 208-6002, www.aethercomm.com.

RS No. 233

120 W Solid-state Amplifier

VENDORVIEW

AR has introduced a new solid-state microwave amplifier, model 120S1G4, that covers 0.8 to 4.2 GHz and has a power output of 120 W. This amplifier employs a new design that delivers more than twice the power of older models. The new, more efficient design consumes less power and incorporates both USB and Ethernet interfaces in addition to the standard IEEE and RS-232 interfaces. With these improvements, AR has maintained the superior rugged design for load tolerance and excellent linearity.

AR RF/Microwave Instrumentation, Souderton, PA (215) 723-8181, www.ar-worldwide.com.

RS No. 234

Power Amplifier

The model AmpLin-PA-50-1 is a 100 W, 2.45 GHz power amplifier. The favourably priced AmpLin-PA-50-1 is an AB class 50 Ohm amplifier within the nominal frequency range of 2.4 to 2.5 GHz. It will support CW, modulated or pulsed input signal schemes into a load of any VSWR. With modulated signals like 64-QAM at 2.45 GHz the amplifier demonstrates good ACPR performance with 51 dBc at 35 W of linear power. Features include: RF output power > 50 dBm, RF input power < 10 dBm, reverse power protection with isolator, input RL > 20 dB and output RL > 26 dB, and compact case design.

Heuermann HF-Technik GmbH, Stolberg, Germany, +49 2402/9749764, www.HHFT.de.

RS No. 235

Detector Log Video Amplifier

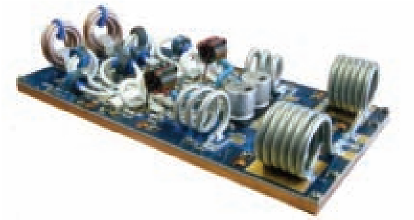
VENDORVIEW

MITEQ Inc. introduces a new addition to its family of Detector Log Video Amplifiers (DLVA). The FBLA-2/6-50 ultra-broadband unit, which operates in the 2 to 6 GHz range, is a low noise, high dynamic range amplifier that utilizes improved sensitivity. The Kovar housing is hermetically-sealed and also fully EMI shielded. Total weight is approximately 20 grams and dimensions are 1.63" × 1.25" × 1.5" without SMA connectors. Featuring fast rise time and a logarithmic linearity of ±1 dB maximum at center frequency at 25°C. Dynamic range is 50 dB and with the addition of a MITEQ LNA, the input power level can be extended down to -70 dBm.

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

RS No. 236

High Power Pallet Amplifier



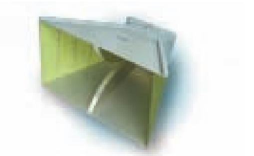
The PP88-108-1500 is a high power Class AB Pallet Amplifier providing 1500 W CW power output. Featuring the latest generation of LD-MOS transistors, the PP88-108-1500 provides the most CW FM power available anywhere in the world today. Thermal tracking bias allows the PP88-108-1500 to operate Class AB providing 1500 W PEP with typical two-tone IMDs of -30 dB, making it an excellent choice for the Digital FM market.

Power Module Technology Inc., Carson City, NV (775) 883-1122, www.pmtrf.com.

RS No. 237

Antenna

Broadband Horn Antennas



Cobham Sensor Systems' H-1734 series broadband linear horn antennas provide superior performance for use in a wide variety of laboratory, commercial and military applications. With excellent input VSWR over the 0.5 to 6 GHz band, these antennas provide high gain across the frequency range and consistent pattern performance. They have become a laboratory standard as a reference horn in anechoic chambers and outdoor ranges. The H-1734 is available with a N-female connector.

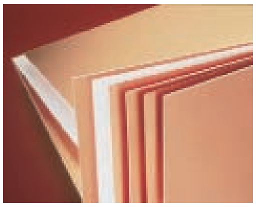
Cobham Sensor Systems, Lansdale, PA (215) 996-2416, www.cobhamdes.com.

RS No. 238

Material

Antenna Grade Laminates

VENDORVIEW



RO4730™ LoPro™ laminates are designed for base station, RFID and other antenna designs. RO4730 LoPro laminate materials combine low-loss dielectric with low-profile copper foil for reduced passive intermodulation (PIM) and low insertion loss. The specially formulated RO4730 LoPro thermoset resin system incorporates a hollow microsphere filler to achieve a low weight, light density laminate, which is approximately 30 percent lighter weight than woven-glass PTFE materials. RO4730 LoPro laminates have a matched dielectric constant of 3.0, providing a lower cost solution for high frequency circuit boards used in base station and other antennas.

Rogers Corp.,
Chandler, AZ (480) 961-1382,
www.rogerscorp.com.

RS No. 239

Software

Design Software

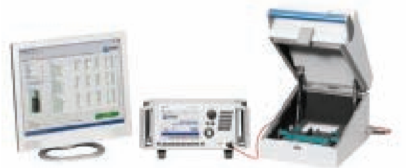
VENDORVIEW

Version 2009 of AWR's Microwave Office design suite is the latest release of AWR's flagship product. It features new MRHB technology that dramatically increases the speed and reduces the computer memory required to perform steady-state analysis of complex nonlinear systems with multiple signal sources. Microwave Office Version 2009 includes a wide array of new features as well, including: expanded support for Open Access (OA) Process Design Kits (PDK), constant output power simulation, enhanced load-pull analysis, behavioral model support for Mesuro's active load-pull system, and customizable project tree that can reconfigure nodes to allow better organization of large projects supporting hundreds of schematics and graphs.

AWR,
El Segundo, CA (310) 726-3000,
www.awrcorp.com.

RS No. 240

TETRA Testing Software



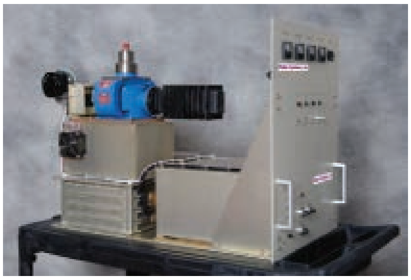
This latest release of the Lector test automation software adds support for TETRA radio testing. The same software used to simplify GSM, WCDMA and CDMA2000 handset testing now provides TETRA terminal testing with just a few mouse clicks. Lector speeds up testing in repair centers as technicians can run tests on several test stations simultaneously from one PC. Results are reproducible and traceable and the software can also automate daily testing of TETRA terminals for emergency first responders.

Willtek Communications GmbH,
Ismaning, Germany +49 (0) 99641 200,
www.willtek.com.

RS No. 241

Sources

Solid-state Power Supply Modulator



Customers using the solid-state power supply modulator for radar systems have been extremely satisfied with the performance of the company's systems in various bands and power levels. The latest advances in power electronics and computer software has enabled Pulse Systems (PSI) to design a new generation of transmitters for the radar industry. One of the most important parameters of the system is the regulation of the transmitted pulse energy that affects the Doppler quality of the radar system. Power supply tight regulation and modulator stability is of the utmost importance in order for the systems to offer reasonable data in terms of the speed of moving storms and of rain precipitation. PSI has been deeply involved in dual polarization systems in all C-, X-, and S-band for more weather detail information demanded by radar users.

Pulse Systems Inc. (PSI),
Canton, MA (781) 828-1142,
www.pulsesystem.com.

RS No. 242

Voltage-controlled Oscillator

The model CRO3562A-LF is an RoHS compliant voltage-controlled oscillator (VCO) in S-band. The CRO3562A-LF operates in a frequency range from 3560 to 3564 MHz with a tuning voltage range of 1.5 to

4.5 VDC. This VCO features a typical phase noise of -112 dBc/Hz at 10 kHz offset and a typical tuning sensitivity of 8 MHz/V. The CRO3562A-LF is designed to deliver a typical output power of 3.5 dBm at 5 VDC supply while drawing 17 mA (typical) over the temperature range of -40° to 85°C. This VCO features typical second harmonic suppression of -35 dBc and comes in Z-Comm's standard MINI-16-SM package measuring 0.5" × 0.5" × 0.22".
Z-Communications Inc.,
San Diego, CA (858) 621-2700,
www.zcomm.com.

RS No. 243

Test Equipment

Test Software

VENDORVIEW

Anritsu Co. introduces software packages that address the emerging 3GPP LTE TDD (Time Division Duplex) technology. The three packages, for use with Anritsu's MG3700A Vector Signal Generator and MS269xA Signal Analyzer Series, expand Anritsu's LTE test portfolio to include solutions that can accurately measure devices, chipsets and equipment designed for either LTE TDD or LTE FDD (Frequency Division Duplex) mode. The MX370110A LTE TDD IQproducer creates 3GPP LTE TDD waveform patterns on a computer for use with MG3700A Vector Signal Generator. The MX269910A LTE TDD IQproducer and MX269022A LTE TDD Downlink measurement packages allow a single MS269xA Signal Analyzer to conduct cost-effective evaluations of both transmitter and receiver characteristics of LTE TDD signals.
Anritsu Co.,
Morgan Hill, CA (408) 778-2000,
www.us.anritsu.com.

RS No. 244

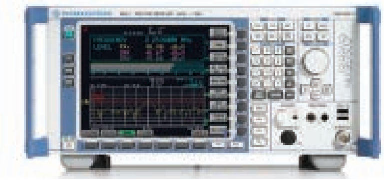
Reverse Recovery Tester

The AVR-CD1-B is a high performance, GPIB and RS232-equipped instrument intended for reverse recovery time testing of diodes and other semiconductor devices. The AVR-CD1-B applies a forward bias pulse of +0.1 to +10 A to a device under test (DUT). At the end of that pulse, the current ramps downward at an adjustable rate of 100 to 200 A/µs until the diode stops conducting. The current waveforms generated by this instrument are suitable for MIL-STD-750E Method 4031.4 Test Condition D tests. Standard and customized jigs for different device packages are available.
Avtech Electrosystems Ltd.,
Ottawa, Ontario, Canada (888) 670-8729,
www.avtechpulse.com.

RS No. 245

EMI Test Receiver

VENDORVIEW



The R&S ESCI7 CISPR 16-1-1 compliant EMI test receiver for the 9 kHz to 7 GHz frequency range meets the requirements of the current edition of the CISPR 22/EN 55022 standard for information technology equipment, which will be valid from 2010. Thanks to an integrated spectrum analyzer, the test receiver can perform standard measurements typically encountered in RF development labs. The receiver can measure phase noise, occupied bandwidth and adjacent channel power, for example, or determine the third-order intercept point. The R&S ESCI7 features a low displayed average noise level (typically -153 dBm at 1 GHz and 10 Hz bandwidth) and a wide dynamic range (1 dB compression point of +5 dBm).
Rohde & Schwarz,
Munich, Germany +49 89 4129 13774,
www.rohde-schwarz.com.

RS No. 246

SR1 Dual-domain Audio Analyzer

The SR1 audio analyzer offers high performance such as -110dB THD+N, ±0.008 dB flatness and 24-bit/192 kHz digital audio. It is the ideal analyzer for analog audio, digital audio and cross-domain audio signal analysis. Measurements include level, THD+N, harmonic distortion, IMD, FFT, frequency response, multi-tone, crosstalk, histogram, jitter amplitude and spectrum. Options include a digital audio carrier digitizer with eye-diagrams and carrier spectra, multi-channel I/O switchers, and an atomic rubidium system clock. Price: $6,900.
Stanford Research Systems Inc.,
Sunnyvale, CA (408) 744-9040,
www.thinksrs.com.

RS No. 247

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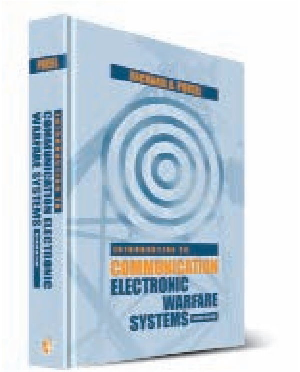

Richard Poisel

Focusing mainly on the engineering aspects of communications electronic warfare (EW) systems, this thoroughly updated and revised edition of a popular Artech House book offers a current and complete introduction to the subject. The second edition adds a wealth of new material, including expanded treatments of two critical areas—RF noise and the effects of signal fading. Moreover, there is now a complete chapter on the important topic of jamming performance over fading channels. The book details the components, systems and operations of electronic warfare systems dedicated to protecting and attacking military communications networks.

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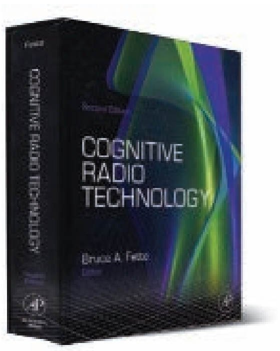
16 Sussex St. · London SW1V 4RW, UK · +44 (0)20 7596-8750
640 pages; $159, £99 · ISBN: 978-1-59693-452-8

Cognitive Radio Technology



Bruce A. Fette, Ed.

This book thoroughly covers current knowledge about cognitive radio (CR) concepts, principles, standards, spectrum policy issues and product implementation details. In addition to 16 chapters that cover all the basics of cognitive radio, this new edition contains eight brand-new chapters covering cognitive radios in multiple antenna systems, policy language, the policy engine, spectrum-sensing and rendezvous techniques, spectrum-consumption models, protocols for adaptation, cognitive networking and information on the latest standards, thus making it a valuable resource for radio frequency and wireless engineers.

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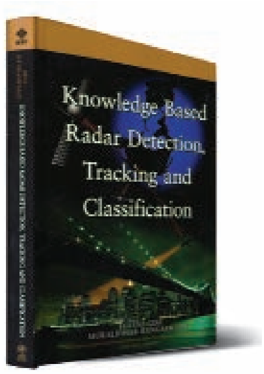
Knowledge Based Radar Detection, Tracking and Classification



Fulvio Gini and Muralidhar Rangaswamy

This book brings together the key concepts essential for the application of Knowledge Based Systems (KBS) to radar detection, tracking, classification and scheduling. It highlights the latest advances in the field and forecasts the impact of KBS technology on future systems, including civilian, military and homeland defense applications. Throughout the book, the authors offer examples of how KBS works and how it can dramatically improve radar performance and capability.

To order this book, contact:

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Career Corner

Making a Connection

Most studies find that 60 to 70 percent of jobs are found via networking and not through the normal job posting and application process. In addition, there are a number of jobs that are never posted on web sites or advertised as they are filled directly via networking. So there is no doubt that networking should be a critical component in a job search. Networking can be done through family members, neighbors, work associates, clubs or even strangers that you strike up a conversation with on a plane or at an event. It can be worked into the conversation whether it is just asking for job search advice or directly asking if they know of any open positions in their industry.

As online social networking is quickly rising in popularity, these types of web sites have become an important networking tool. LinkedIn is viewed as the leading professional oriented social networking web site with over 44 million users, but Plaxo with Simply Hired, Jobster, Facebook, Craig's List and Ecademy are other popular sites. Many employers are using Twitter to promote their openings to find qualified applicants.

Take full advantage of sites like LinkedIn by completing your entire profile. State that you are a job seeker and list your expertise, experience and education. Build your network by finding people you know or are associated with and obtain recommendations from those who know your work. If you find a job opening, search your network and see if you can find help in getting endorsements from others who might have relationships with the job provider.

Join groups that are related to your industry of interest (for example, *Microwave Journal* started the RF and Microwave Community on LinkedIn) and contribute ideas, news and discussion topics. Monitor and search the jobs section in each group and exchange information with various recruiters in the group and on the site. Other groups such as industry associations, alumni groups, special interest groups, etc. are also valuable in the same way.

Twitter has quickly become a popular social networking tool that is sometimes difficult to understand when it comes to using it for purposes other than just tweating about what you are doing. Again it is important to have a complete profile with a useful link about job qualifications and it is critical to build up a quality group of followers. Choose to follow the companies that would have job openings of interest as they at times will tweat about them. Participate in discussions and even post what kind of job you are interested in obtaining and ask for help in your search.

Be creative and build your brand online. Start a blog in your area of expertise and establish yourself as an experienced person in that area. Create a video resume on Youtube.com. List links to articles or papers you have published or blogs to which you have contributed. Personal and social networking could provide the inside route to your next job.

Pat Hindle
Editor, Microwave Journal

Useful web sites for jobseekers and companies that need qualified applicants:

ElectroMagneticCareers.com

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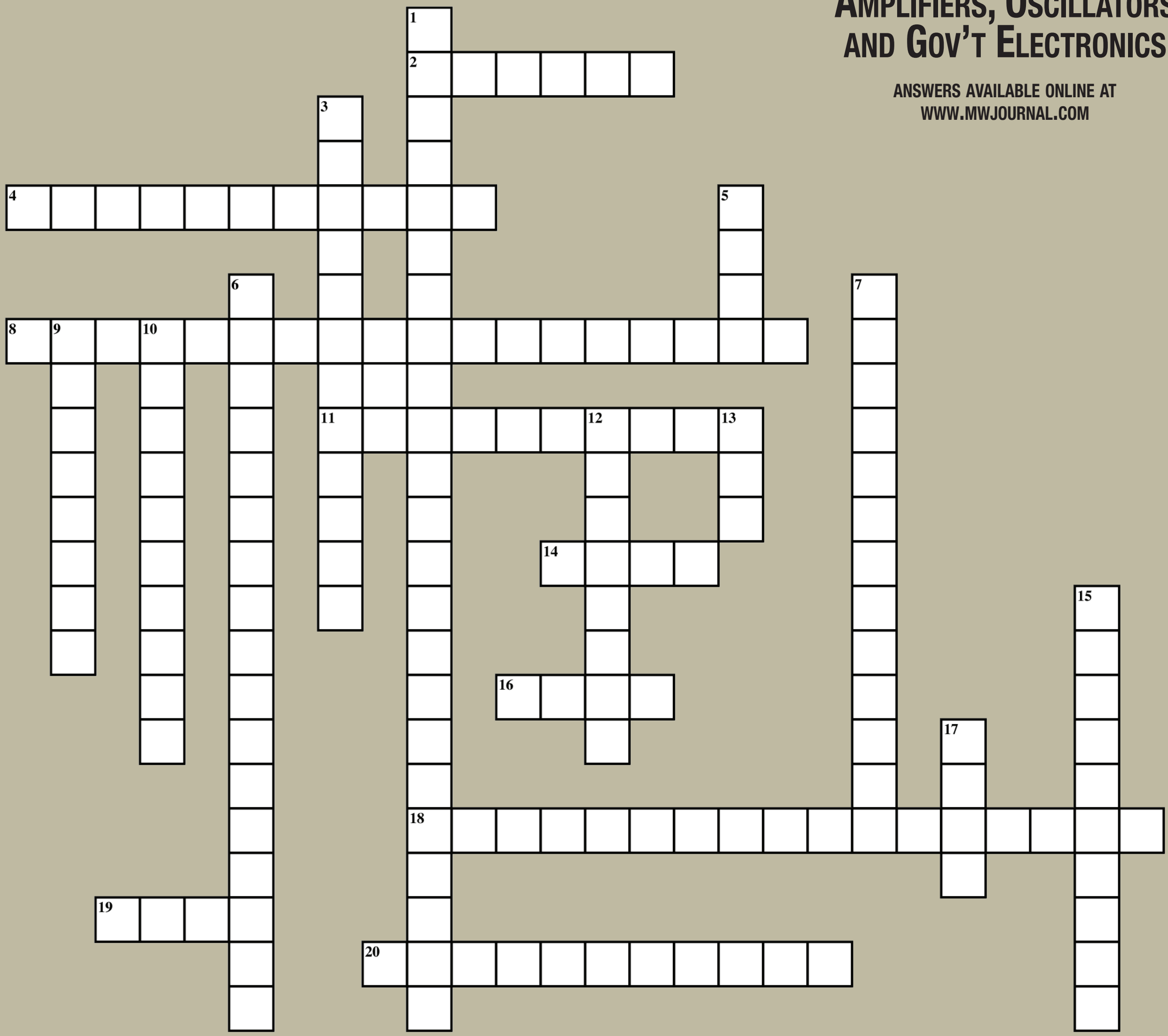

ACROSS

2 The frequency interval from 1 to 2 GHz (hyphenated)
4 802.16e (2 words)
8 The matching of the modulation, coding and other signal and protocol parameters to the conditions on the radio link (2 words)
11 The level of signal below which a receiver cannot detect a signal due to the noise generated within the receiver (2 words)
14 National Telecommunications and Information Administration
16 Adjacent-channel leakage ratio
18 YIG (3 words)
19 American Recovery and Reinvestment Act
20 Linearization technique to remove unwanted nonlinear effects by correcting them after they occur (2 words)

DOWN

1 GPS (3 words)
3 $1/f$ noise (2 words)
5 Oven controlled crystal oscillator
6 Wireless middle mile solution that is typically cost effective for rural area coverage (2 words)
7 Linearization technique to remove unwanted nonlinear effects by adjusting the input signal to remove them
9 A circuit or component that allows a communications system to simultaneously transmit and receive signals through a common component, such as an antenna
10 A measure of the random phase instability of a signal (2 words)
12 The final leg of delivering connectivity from a communications provider to a customer (2 words)
13 Rural Utilities Service
15 The backhaul portion of the network that carries the traffic to the network core (2 words)
17 Traffic Collision and Avoidance System

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Active Bias & ESD Protection
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2009 translates in Roman numerals to "MMIX," so Mimix Broadband is celebrating by declaring 2009 the Year of MMIX. We're highlighting key advances in our product portfolio and paying tribute to other engineering feats – specifically the Seven Wonders of the Modern World as chosen by the American Society of Civil Engineers. Learn more at www.mimixbroadband.com/year-of-MMIX.

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HIGH POWER DEVICES

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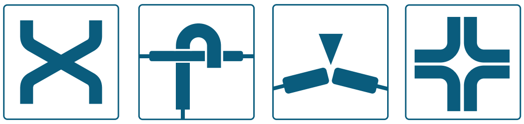
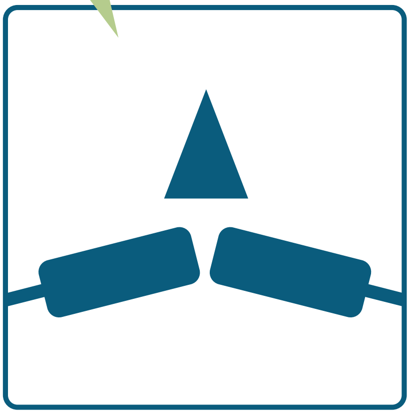


Breaking all the Rules

High Power Combiners

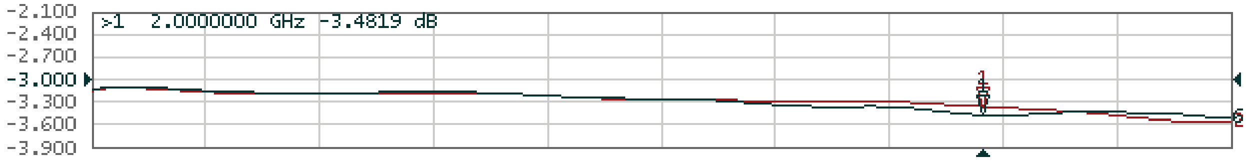
- 10:1 + Bandwidth
- Full Input Failure Protection
- Capable of Non-Coherent Combining

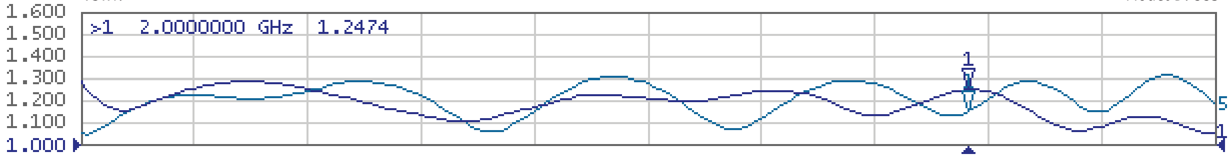


COMBINERS

**Multi-Section Power Dividers, first described by Seymour Cohn, employ a large number of floating, high value resistors, resulting in excessive high frequency roll-off and low unbalanced power capability.

Werlatone's, Patent Pending **"Collapsed Cohn" design requires only one or two, low value, high power resistors to provide the same port-to-port isolation and higher unbalanced power protection, while eliminating high frequency roll-off.





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Model	Type	Frequency (MHz)	Power (W CW)	Insertion Loss (dB)	VSWR	Isolation (dB)	Size (Inches)
D7885	2-Way	200-2500	200	0.65	1.40:1	15	7.7 x 1.6 x 1.1
D7823	2-Way	500-2500	200	0.4	1.35:1	15	4.7 x 2.0 x 0.8
D7630	2-Way	800-3000	200	0.4	1.35:1	15	3.7 x 1.9 x 0.87
D7539	4-Way	800-2800	200	0.6	1.35:1	17	5.5 x 4.1 x 1.1
D7695	4-Way	900-1300	100	0.4	1.30:1	20	4.0 x 3.3 x 0.8