Vol. 49 • No. 8

August 2006

# Microwave Journal

## European Microwave Week 2006

### G-MEX/MICC, Manchester, UK

**Conference and Exhibition Preview**

**European Special Report**

**Characterization of Ultra-wideband Bow-tie Antennas**

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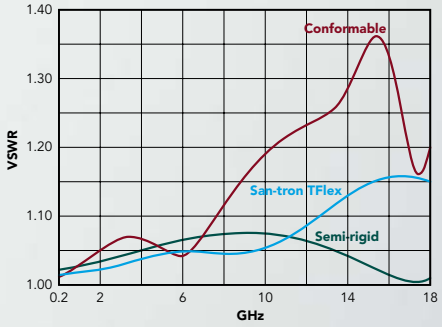


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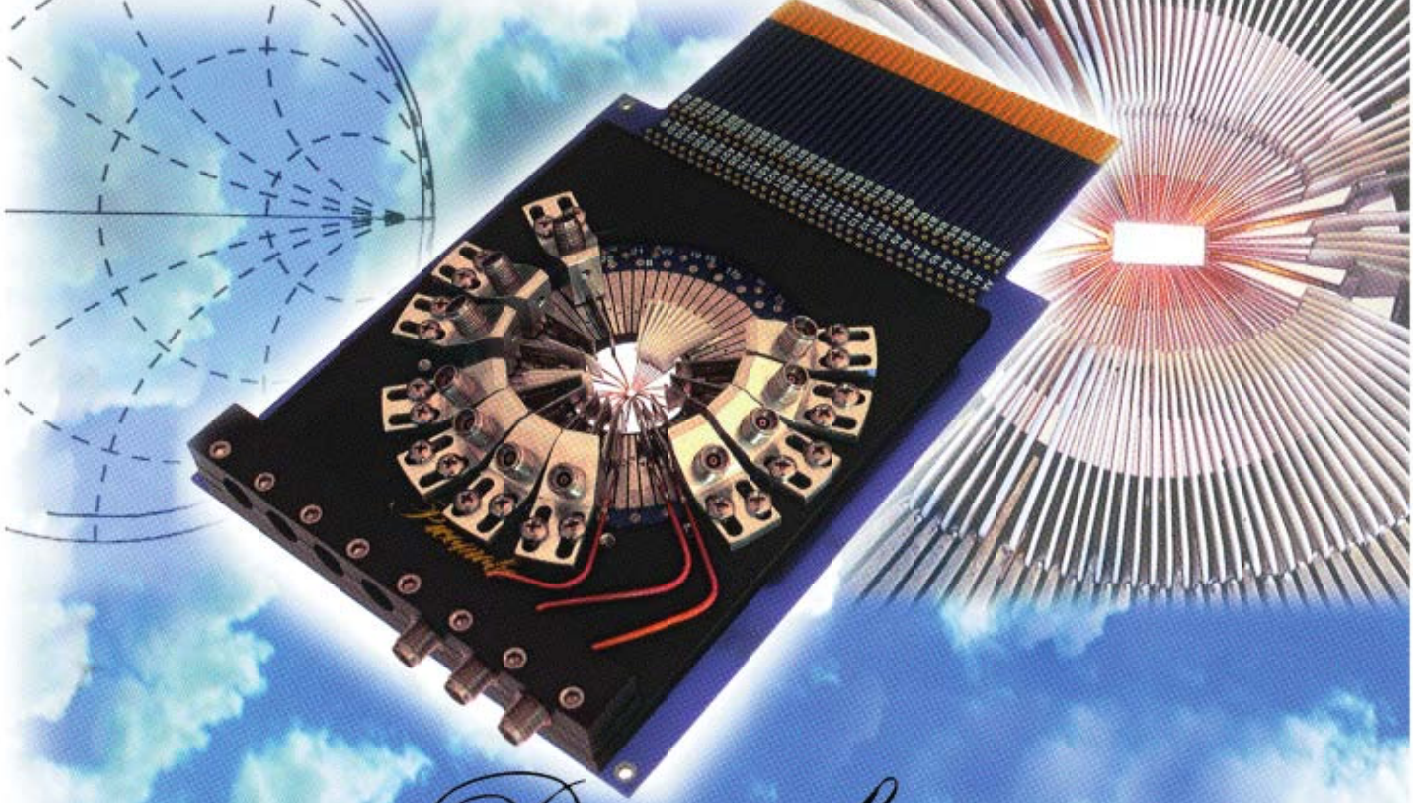

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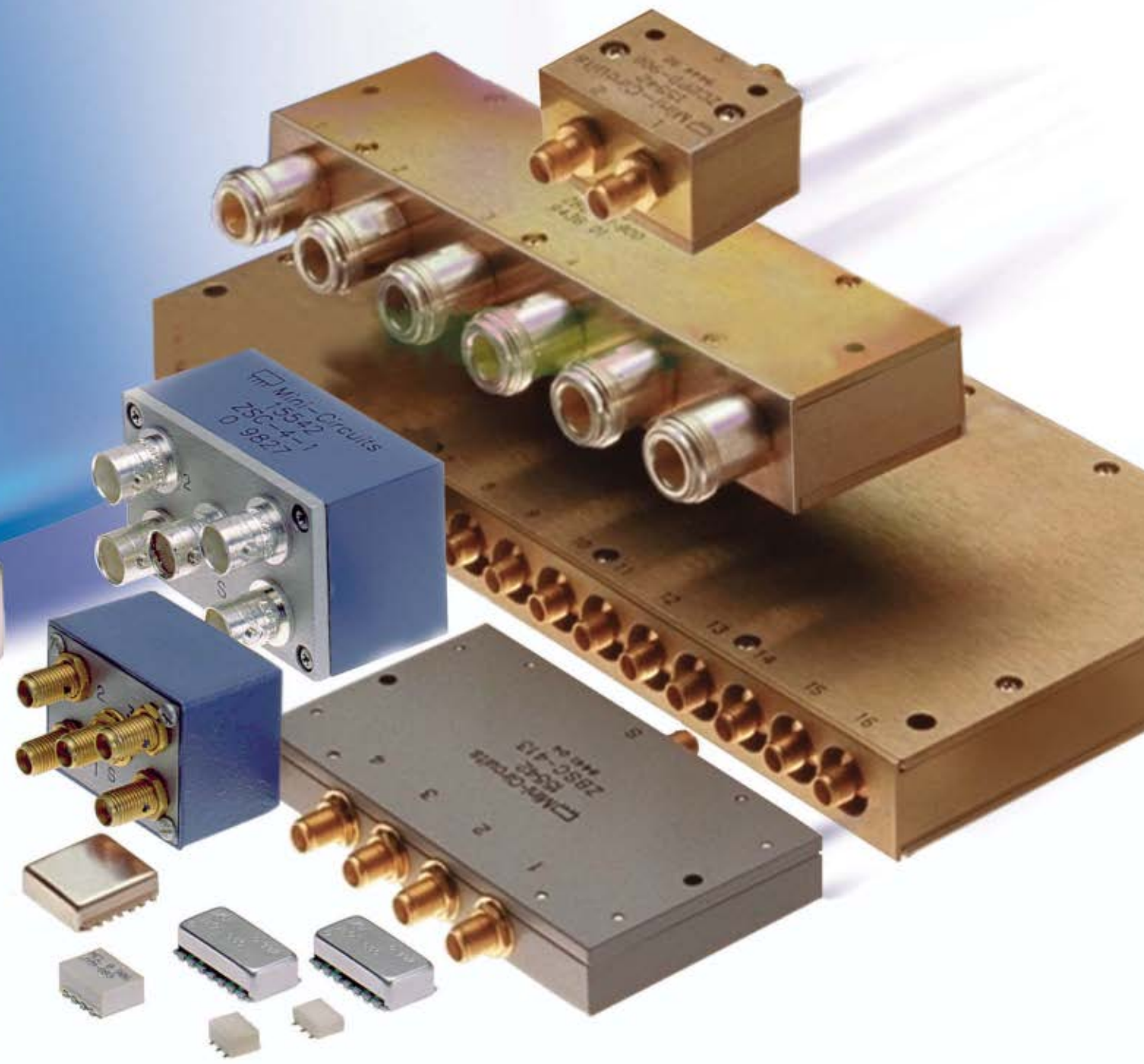
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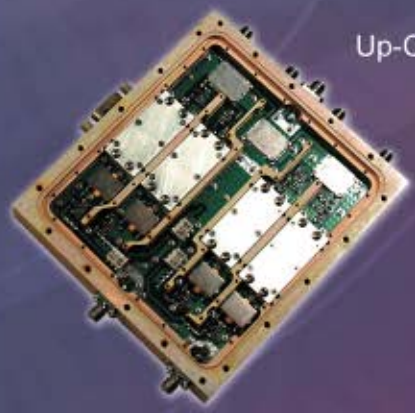

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## AVAILABLE USB TUNER MODELS

| FREQUENCY RANGE (GHz) | | | MODEL | VSWR MATCHING RANGE (MIN) |
|---|---|---|---|---|
| 0.25 | – | 2.5 | MT981AU01 | 15:1 |
| 0.4 | – | 4.0 | MT981BU | 15:1 |
| 0.4 | – | 2.5 | MT981BU05 | 30:1 |
| 0.4 | – | 0.5 | MT981BU06 | 30:1 |
| 0.5 | – | 2.2 | | 40:1 |
| 2.2 | – | 2.5 | | 30:1 |
| 0.4 | – | 0.5 | MT981BU06A | 30:1 |
| 0.5 | – | 2.2 | | 40:1 |
| 2.2 | – | 3.0 | | 30:1 |
| 0.8 | – | 8.0 | MT981EU | 15:1 |
| 0.8 | – | 8.0 | MT981EU02 | 15:1 |
| 0.8 | – | 5.5 | MT981HU11 | 100:1 |
| 0.8 | – | 5.5 | MT981HU21 | 100:1 |
| 0.8 | – | 5.5 | MT981HU31 | 100:1 |
| 0.8 | – | 2.0 | MT982EU30 | 30:1 |
| 2.0 | – | 8.0 | | 15:1 |
| 1.8 | – | 18.0 | MT982AU01 | 10:1 |
| 1.8 | – | 18.0 | MT982AU02 | 15:1 |
| 1.8 | – | 4.2 | MT982AU11 | 20:1 |
| 3.7 | – | 8.2 | MT982AU12 | 20:1 |
| 8.2 | – | 18.0 | MT982AU13 | 20:1 |
| 0.8 | – | 18.0 | MT982BU01 | 10:1 |
| 0.8 | – | 8.0 | MT982EU | 15:1 |
| 0.8 | – | 50.0 | MT984AU01 | 10:1 |

MT981EU

MT982AU02

MT982BU01

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AUGUST 2006 VOL. 49 • NO. 8

# EUROPEAN MICROWAVE WEEK 2006

## GUEST EDITORIAL



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|---|---|---|---|---|---|
| **WiMax (GaAs PHEMT)** | | | | | |
| MAAP-003438-005PP0 | 3400-3800 | 5 | 10.5 | 12 | 27 @ 0.5W Avg |
| MAAP-003438-010PP0 | 3400-3800 | 10 | 10.5 | 12 | 20 @ 1W Avg |
| MAAP-003438-030CF0 | 3400-3800 | 30 | 10.5 | 12 | 20 @ 3W Avg |
| **LDMOS** | | | | | |
| MAPLST0822-002PP | 800-2200 | 2 | 20 | 28 | 50 |
| MAPL-000817-015C00 | 800-1700 | 15 | 17 | 26 | 50 |
| MAPLST1617-030CF | 1600-1700 | 30 | 14 | 28 | 50 |
| **IFF/TACAN (Si BJT, Short Pulse)** | | | | | |
| MAPRST0912-50 | 960-1215 | 50 | 9.5 | 50 | 46 |
| MAPRST0912-350 | 960-1215 | 350 | 9.6 | 50 | 50 |
| MAPRST1030-1KS | 1030 | 1000 | 8.8 | 50 | 53 |
| **L-Band (Si BJT, Long Pulse 6ms, 25%)** | | | | | |
| MAPRST1214-6UF | 1200-1400 | 6 | 9 | 36 | 45 |
| MAPRST1214-30UF | 1200-1400 | 30 | 7.9 | 36 | 49 |
| MAPRST1214-150UF | 1200-1400 | 150 | 7.9 | 36 | 49 |
| **S-Band (Si BJT, Medium Pulse)** | | | | | |
| MAPRST2729-170M | 2700-2900 | 170 | 9 | 36 | 45 |
| * MAPPST2729-170M | 2700-2900 | 170 | 9 | 36 | 45 |
| * MAPPST2729-300M | 2700-2900 | 300 | 8.7 | 36 | 46 |
| * MAPPST2933-190M | 2900-3300 | 190 | 8 | 36 | 38 |

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Microwave Journal

# FEATURES

## SPECIAL REPORTS



## APPLICATION NOTE



## TECHNICAL FEATURES



# DID YOU KNOW?

FACT #1: TIGER STRIPES ARE AS UNIQUE AS HUMAN FINGERPRINTS AND AREN'T JUST ON THE SURFACE... TIGERS HAVE STRIPED FUR AND SKIN.

FACT #2: TRIQUINT'S 22-YEAR HISTORY IN GaAs JUST SCRATCHES THE SURFACE OF OUR DEEP COMMITMENT TO INNOVATIVE NEW MICROWAVE AND MILLIMETER WAVE PRODUCTS.

The tiger is the most widely adapted of the great cats, ranging from the snowy Siberian Steppe to steamy Sumatran jungles. Just like the well-adapted tiger, TriQuint makes its home in a wide range of microwave and high frequency markets, offering products well suited to many needs and applications.

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• Highly adaptive GaAs FETs designed for BWA and WiMAX; a new line in low-cost, partially matched packages that simplify board layout and reduce performance variability around key center frequencies: 2.6, 3.5 and 5.8 GHz.

• Foundry Services: TriQuint Semiconductor created many of the GaAs processes used in today's most popular 'standard' products. We're expanding our low-noise, power and logic applications (DC-80 GHz), offering the industry's widest GaAs process selection: HBT, pHEMT, E/D pHEMT, MesFET, PIN, HFET, mHEMT.

• New SAW filter solutions: Bluetooth, cable STB, BWA and WiMAX applications are all served, plus new base station filters for GSM / EDGE, CDMA and WCDMA.

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# FEATURES

## TECHNICAL FEATURE



## PRODUCT FEATURES



# DEPARTMENTS



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**EXECUTIVE EDITORIAL OFFICE:**
685 Canton Street, Norwood, MA 02062
Tel: (781) 769-9750
FAX: (781) 769-5037
e-mail: mwj@mwjournal.com

**EUROPEAN EDITORIAL OFFICE:**
46 Gillingham Street, London SW1V 1HH, England
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# GaAs Microwave Diodes

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### GaAs Schottky Diodes - Flip Chip

| Model | Configuration | $V_F$ MIN m V | $V_F$ MAX mV | $V_{BR}$ Min V | $C_J$ Max pF | $R_S$ Max Ω |
|---|---|---|---|---|---|---|
| MGS801 | Single Junction | 650 | 750 | 5 | 0.05 | 7 |
| MGS801A | Single Junction | 650 | 750 | 5 | 0.075 | 5 |
| MGS802 | Anti-Parallel Pair | 650 | 750 | -- | 0.10 | 7 |
| MGS802A | Anti-Parallel Pair | 650 | 750 | -- | 0.15 | 5 |
| MGS803 | Series Tee | 650 | 750 | 5 | 0.06 | 7 |

### GaAs Schottky Diodes - Beam Lead

| | | | | | | |
|---|---|---|---|---|---|---|
| MGS901 | Single Junction | 650 | 750 | 5 | 0.06 | 7 |
| MGS902 | Anti-Parallel Pair | 650 | 750 | -- | 0.10 | 7 |
| MGS903 | Series Tee | 650 | 750 | 5 | 0.06 | 7 |
| MGS904 | 4 Junction Ring Quad | 650 | 750 | -- | 0.06 | 7 |
| MGS905 | 4 Junction Bridge Quad | 650 | 750 | 5 | 0.06 | 7 |
| MGS906 | 4 Junction Series Tee | 1300 | 1500 | 10 | 0.04 | 14 |
| MGS907 | 8 Junction Ring Quad | 1300 | 1500 | -- | 0.04 | 14 |
| MGS907A | 8 Junction Ring Quad | 1300 | 1500 | -- | 0.06 | 12 |
| MGS907B | 8 Junction Ring Quad | 1300 | 1500 | -- | 0.08 | 10 |
| MGS908 | 8 Junction Bridge Quad | 1300 | 1500 | 10 | 0.04 | 14 |
| MGS909 | 6 Junction Series Tee | 1800 | 2100 | 15 | 0.10 | 21 |
| MGS910 | 12 Junction Ring Quad | 1800 | 2100 | -- | 0.10 | 21 |
| MGS911 | 12 Junction Bridge Quad | 1800 | 2100 | 15 | 0.10 | 21 |
| MGS912 | Four Junction Series | 2500 | 2900 | 20 | 0.03 | 28 |
| Test Conditions | | $I_F$ = 1 mA | | $I_R$ = 10 uA | $V_R$ = 0 V F = 1 MHz | $I_F$ = 5 mA |

### GaAs Varactor Diodes

| Model | Γ NOM | $V_{BR}$ V | Available Range of $C_{J4}$ | Tuning Range | | Q |
|---|---|---|---|---|---|---|
| | | | | 2 to 12 V | 2 to 20 V | |
| MGV050-XX | 0.50 | 22 | 0.30 pF to 2.0 pF | 4.7 (0 to 22 V) | | 3,000 to 4,000 |
| MGV075-XX | 0.75 | 22 | 0.30 pF to 2.0 pF | 2.8 | 3.5 | 3,000 to 4,000 |
| MGV100-XX | 1.00 | 22 | 0.30 pF to 2.0 pF | 3.4 | 5.0 | 3,000 to 4,000 |
| MGV125-XX | 1.25 | 22 | 0.30 pF to 2.0 pF | 5.0 | 9.5 | 3,000 to 4,000 |

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### GaAs Schottky Diodes

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"Ask Harlan," a technical question and answer session with Harlan Howe, Jr., an industry veteran and long-time *Microwave Journal* editor, has been a regular part of our web site (www.mwjournal.com) for almost two years now. In an effort to better combine the editorial content of our magazine with our newly developed and retooled on-line presence, we have decided to develop Harlan's RF and microwave engineering advice into a monthly feature.

**How it works:** Harlan has selected one question from his "Ask Harlan" column to be featured in the magazine. Please visit www.mwjournal.com/askharlan to provide an answer to this month's featured question (see below). Harlan will be monitoring the responses and will ultimately choose the best answer to the question. Although all of the responses to the featured question will be posted on our web site, we plan to publish the winning answer in the October issue. All responses must be submitted by **September 5, 2006**, to be eligible for the participation of the August question.

The winning response will win a free book from Artech House, along with an "I Asked Harlan!" t-shirt. In addition, everyone who submits a legitimate response will be sent an "I Asked Harlan!" t-shirt.

## *June Question and Winning Response*

**The June question was submitted by Charles Werner from Gamma Remote Sensing AG:**

Dear Harlan,

1. How good are direct digital synthesizers at generating FMCW signals? I am looking at a system that uses a frequency translation loop Analog Devices AD9858 to get output in the range of 2.1 to 2.3 GHz for an FMCW radar.
2. What is the best way to get this signal heterodyned to the range of 4.1 to 4.3 GHz and what configuration of mixer/LO is recommended/required?

**The winning response to the June question is from Earl McCune of Panasonic:**

Direct digital synthesizers (DDS) are excellent at generating extremely linear frequency ramps. The largest error source in the output frequency ramp linearity comes from any variation in group delay through the DAC output low pass filter (LPF). My recommendation is to keep the maximum DDS output frequency below 15 percent of its clock frequency (fc), and then to use a wider LPF (around 25 to 30 percent of fc) to keep the group delay fairly flat across the signal bandwidth. Depending on the FM sweep rate you are using, you may find the design problem much easier to multiply from the DDS output to your final output frequencies using a PLL. A PLL will be needed anyway to synthesize the additional upconversion LO. If you choose to heterodyne the output, you must keep in mind that the sense of the sweep will invert if you use a high side LO (6.4 GHz). In general, by using high side injection it will be much easier to filter out the heterodyne spurious products.

**Harlan's response:**

Direct digital synthesizers generally produce very clean signals, which should be suitable for an FMCW system. I'm not sure why you want to heterodyne up to 4 GHz rather than using a simple multiplier. The upconversion will be difficult because of the high frequencies at all three ports. There are two possible approaches. You can build a single-ended mixer using the common port of a triplexer filter arrangement. I have done this and it works but not too efficiently because of the filter losses and diode matching problems. You can also use a double balanced mixer with a star configuration of diodes rather than a ring of diodes. This type of converter allows the signal bands to overlap. Unfortunately, I don't believe either approach is available as a commercial product for your frequencies.

## *This Month's Question of the Month*
***(answer on-line at www.mwjournal.com/askharlan)***

**Larissa Marple from Virginia Tech has submitted this month's question:**

Dear Harlan,

Concerning power amplifiers, what is the highest PAE recorded and what design type achieved that efficiency?

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| Model | LO Power (dBm) | Frequency (MHz) LO/RF $f_L$-$f_U$ | IF | Conv. Loss* (dB) Typ. | LO-RF Isol. (dB) Typ. | LO-IF Isol. (dB) Typ. | IP3 @ Center Band (dBm) Typ. | Price $ea. Qty. 10-49 |
|---|---|---|---|---|---|---|---|---|
| SIM-73L+ | +4 | 2400-7000 | DC-3000 | 6.2 | 30 | 22 | +10 | 9.95 |
| SIM-43+ | +7 | 750-4200 | DC-1500 | 6.1 | 35 | 24 | +12 | 7.45 |
| SIM-83+ | +7 | 2300-8000 | DC-3000 | 6.0 | 28 | 20 | +11 | 7.95 |
| SIM-14+ | +7 | 3700-10000 | DC-4000 | 6.7 | 38 | 16 | +16 | 8.95 |
| SIM-153+ | +7 | 3400-15000 | DC-4000 | 7.5 | 36 | 21 | +10 | 9.95 |
| SIM-63LH+ | +10 | 750-6000 | DC-1500 | 6.2 | 34 | 22 | +13 | 8.95 |
| SIM-83LH+ | +10 | 1700-8000 | DC-3000 | 6.0 | 28 | 22 | +11 | 10.95 |
| SIM-153LH+ | +10 | 3200-15000 | DC-4000 | 7.5 | 36 | 20 | +11 | 11.95 |

*Conversion Loss @ 30MHz IF.

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*by October 2, 2006*
IEEE MTT-S International Microwave Symposium
*by December 1, 2006*

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**IRMMW-THz 2006**
*September 18–22, 2006 • Shanghai, China*
www.sitp.ac.cn/irmmw-thz2006

**IEEE INTERNATIONAL CONFERENCE ON ULTRA-WIDEBAND (ICUWB 2006)**
*September 24–27, 2006 • Waltham, MA*
www.icuwb2006.org

## OCTOBER

**HUT-ICCE 2006**
*October 10–11, 2006 • Hanoi, Vietnam*
www.hut-icce.org

**RADIOTECC 2006**
*October 18–19, 2006 • Berlin, Germany*
www.gerotron.com

**28TH ANNUAL SYMPOSIUM OF THE ANTENNA MEASUREMENT TECHNIQUES ASSOCIATION (AMTA 2006)**
*October 22–27, 2006 • Austin, TX*
www.amta.org

## NOVEMBER

**ELECTRONICA 2006**
*November 14–17, 2006 • Munich, Germany*
www.electronica.de

**MM-WAVE PRODUCTS AND TECHNOLOGIES**
*November 16, 2006 • Savoy Place, London*
www.iee.org/events/mmwave.cfm

**68TH ARFTG CONFERENCE**
*November 28–December 1, 2006*
*Broomfield, CO*
www.arftg.org

## JANUARY

**IEEE RADIO AND WIRELESS SYMPOSIUM (RWS 2007)**
*January 9–11, 2007 • Long Beach, CA*
www.radiowireless.org

**IEEE TOPICAL WORKSHOP ON POWER AMPLIFIERS FOR WIRELESS COMMUNICATIONS (PA WORKSHOP)**
*January 8–9, 2007 • Long Beach, CA*
http://paworkshop.ucsd.edu

**7TH TOPICAL MEETING ON SILICON MONOLITHIC INTEGRATED CIRCUITS IN RF SYSTEMS (SiRF 2007)**
*January 10–12, 2007 • Long Beach, CA*
www.ece.wisc.edu/sirf07

## APRIL

**IEEE RADAR CONFERENCE 2007**
*April 17–20, 2007 • Waltham, MA*
www.radar2007.org

## JUNE

**IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM AND EXHIBITION**
*June 3–8, 2007 • Honolulu, Hawaii*
www.ims2007.org

# Workshops & Courses

## On-line course – Introduction to Electronics

■ **Topics:** Based upon the two-day Overview of Electronics course, this new on-line course will introduce the basic ideas behind electronic circuits. The course is designed to act both as an introductory course and a refresher course, and will highlight how electronic systems work and how they are made. For more information, visit www.conted.ox.ac.uk.
■ **Site:** On-line course.
■ **Date:** September 1, 2006
■ **Contact:** University of Oxford Continuing Education, 1 Wellington Square, Oxford, OX1 2 JA UK +44 1865 270360 or e-mail: electronics@conted.ox.ac.uk.

## "Connect" – CST Workshop Series 2006

■ **Topics:** This introductory workshop will be led by Mohan Jayawardene and Ralf Ehmann during EuMW. It is free of charge and will present CST's "Connected" approach to 3D EM simulation. It will provide modern 3D EM simulation tools that offer benefits such as shorter and more cost-effective development cycles through automatic optimization and parameter studies.
■ **Site:** Manchester, UK
■ **Date:** September 13, 2006
■ **Contact:** For more information, visit www.cst.com.

## CONCERTO Software – Introductory Training Course

■ **Topics:** CONCERTO is a state-of-the-art software environment for the design of RF and microwave equipment. Delegates of the course are given instruction by experienced engineers in the Vector Fields team on using CONCERTO to model many applications, including: patch and horn antennas, microwave filters, microstrip and waveguide junctions. Hands-on scripted examples are an integral part of the course, giving delegates the opportunity to explore the easy-to-use interface and powerful post-processing. For more information, visit www.vectorfields.com.
■ **Site:** Oxford, UK
■ **Dates:** October 10–11, 2006
■ **Contact:** For more information, visit www.vectorfields.com.

## Design Troubleshooting, Failure Analysis and Prevention in Electronic Circuits

■ **Topics:** This course covers techniques for troubleshooting design problems both in the laboratory and in field installations. Each technique is discussed in depth, including how to apply it and how to interpret results. Participants learn how to locate and deal with the sources of noise that cause problems in designs, including noise-related reliability problems in system, board and device design. For more information, visit www.unex.berkeley.edu.
■ **Site:** San Francisco, CA
■ **Date:** October 26, 2006
■ **Contact:** UC Berkeley Extension, 1995 University Avenue, Berkeley, CA 94720 (510) 642-4151 or e-mail: course@unex.berkeley.edu.

## Far-field, Anechoic Chamber, Compact and Near-field Antenna Measurements

■ **Topics:** This course presents the state-of-the-art in antenna measurements, including far-field, anechoic chamber, compact and near-field measurements. The course also includes range evaluation and compensation techniques and microwave holography. For more information, visit www.pe.gatech.edu.
■ **Site:** Atlanta, GA
■ **Dates:** November 6–10, 2006
■ **Contact:** Georgia Institute of Technology, Professional Education, PO Box 93686, Atlanta, GA 30377 (404) 385-3500.

## The Entrepreneurial Engineer

■ **Topics:** This short course is an efficient and memorable introduction to the personal, interpersonal, business and organizational skills necessary to help engineers of applied science and mathematics perform at high levels in today's increasingly opportunistic organizations and enterprises. For more information, visit http://online.engr.uiuc.edu/shortcourses/tee/index.html.
■ **Site:** Archived on-line course.
■ **Dates:** Archived on-line for anytime viewing.
■ **Contact:** University of Illinois at Urbana-Champaign, 117 Transportation Bldg., 104 S. Mathews Avenue, Urbana, IL 61801 (217) 333-0897 or e-mail: deg@uiuc.edu.

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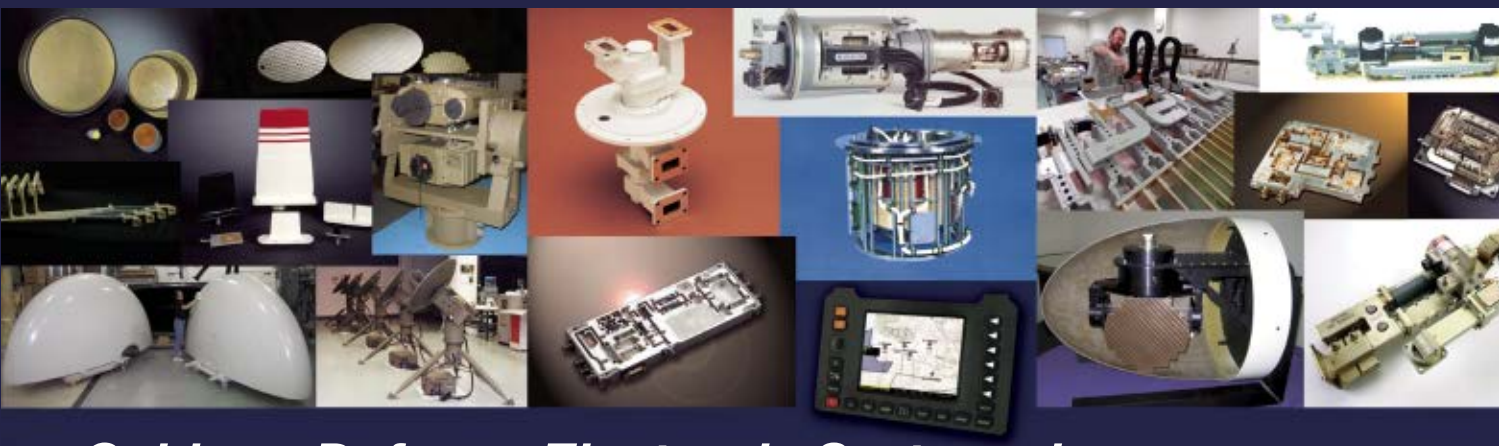

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# WELCOME TO EUROPEAN MICROWAVE WEEK 2006

It is a new venue, a new location and an extended format as the home city of Manchester United Football Club plays host to the 9th European Microwave Week. Now extended to six days, the Week has just one goal — to offer four strong and challenging conferences, balanced by a healthy exhibition featuring international players and complemented by a vibrant social agenda. Europe's premier RF and microwave event kicks off on 10 September through to 15 September at the city's G-MEX/MICC Complex, where a capacity crowd is expected to divulge and discuss the latest trends and developments that are widening the field of application of modern microwaves.

Supporters of our industry will be made to feel welcome as Manchester stages the event for the first time, before it travels to Munich in 2007 and Amsterdam in 2008. This year, just as the historical city of Manchester has profited from regeneration, the established conferences have also had a makeover with the introduction of the European Microwave Integrated Circuits Conference (formerly the GAAS Symposium), which is the product of close collaboration between the GAAS Association and the European Microwave Association. The new format will enable it to slot in well and complement the established 36th European Microwave Conference (EuMC 2006); the European Conference on Wireless Technology (ECWT 2006); and the European Radar Conference (EuRAD 2006).

Playing its now familiar mid-field role will be the three-day European Microwave Week Exhibition. It is central to the week and fittingly is being staged in the Central Hall of the G-MEX Centre from 12 to 14 September. The venue, a transformed former train station, is on track to welcome international players, not just from Europe, but from across the globe with strong representation from the US and Asia who recognise the significance of the exhibition to showcase their wares to a wide and focussed audience. The exhibition provides a stage for companies, large and small, established or new start-ups, to spotlight their latest introductions, discuss possible future developments and get feedback from customers. For those wanting to

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get hands-on experience and guidance direct from the experts there are also workshops and short courses on various subjects.

European Microwave Week always strives to balance work and play by offering a rich calendar of social events and this year is no exception. Highlights include the EuMW Welcome Reception that has now become synonymous with the event as it encourages the interaction between academia and industry. There will be the first EuMIC Dinner, which joins the EuRAD Dinner, and there is also the opportunity to attend the EuMW Gala Dinner at the home of Manchester United Football Club, Old Trafford. Alongside, there are other social events throughout the week and tourist programmes to enable visitors to sample Manchester and the surrounding area.

For Manchester's famous soccer club to become successful has taken a great deal of teamwork and the same team effort has been put into European Microwave Week 2006. A large number of enthusiasts in industry and universities from the UK, Ireland, across Europe and the US have helped out. On behalf of the local organising committee we would like to thank the four international technical programme committees and the hundreds of reviewers who worked tirelessly to shape the record number of individual contributions into the final programmes. We would like to acknowledge the EuMA Board for its continued advice and guidance, and we wish to thank the Horizon House personnel assigned to this event for their invaluable support in organising this major international event, as well as their contribution in staging a world-class exhibition. Last but not least, we acknowledge the financial and in-kind sponsorship of many industrial enterprises and other organisations.

Great efforts have been made to ensure that European Microwave Week's first visit to Manchester is a productive and memorable one. It gives the RF and microwave industry the perfect arena to showcase its undoubtable skills and with your continued support we hope to build on past successes and take the event into a new league. The entire team looks forward to welcoming you to the 9th European Microwave Week. ■

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# ATTENDING EUROPEAN MICROWAVE WEEK 2006

Manchester, UK is regarded as the home of the Industrial Revolution, and will fittingly host the 2006 European Microwave Week from Sunday 10 September to Friday 15 September, to promote the RF and microwave industry's current invention and productivity. Aptly too, the G-MEX/MICC that will house this flagship event has its own industrial lineage and is a prime example of the regeneration that typifies modern Manchester — it is a former train station that will provide the ideal platform for the industry to display its skills and expertise. The city has been a major port and trading centre since the 1700s but in 2006 visitors to EuMW will be trading ideas and views at the four major conferences and introducing and marketing their products at the European Microwave Exhibition.

A great deal of effort has gone into ensuring that the Week is not only informative and productive but also relaxed and sociable. The conferences reflect our industry's innovation and endeavour, covering all aspects of RF, microwave, millimetre and submillimetre-wave engineering including microwave and photonic devices, component technologies, circuits and systems. The programme embraces theoretical, experimental and applications-oriented approaches to wireless, radar, device and circuit technologies and industrial applications, as well as addressing emerging technologies and topical subjects such as ultra-wideband technologies, power amplifiers and linearization, terahertz technologies and MEMS. The increasing interest in industrial and applications-oriented research is also evident and is a focus of the wide variety of workshops, short courses and focused sessions being run.

There is nothing more practical and applications-oriented than the actual products that are borne from such research and development and these can be found at the European Microwave Week Exhibition in the Central Hall of the G-MEX Centre. Spanning three days (Tuesday, Wednesday and Thursday) the exhibition has made its presence felt over recent years and established itself as the premier RF and microwave trade show in Europe. It attracts leading industry players not just from Europe but also from around the globe with North America providing significant numbers and Asian participation expanding rapidly. Visitors can see first hand the latest innovations and new product introductions, discuss specific areas of interest with development engineers and find the right products for their specific applications.

The official European Microwave Week opening ceremony on Monday morning is open to delegates from all conferences, while Tuesday sees the EuMW Welcome Reception (see Social Events), which has become a highlight of the week. Open to delegates and exhibitors it provides the unique opportunity for academia and industry to get together to eat, drink and exchange ideas socially. It is also a thank you to all those that attend and participate at EuMW 2006.

RICHARD MUMFORD
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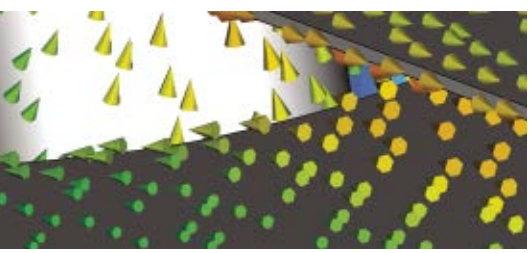

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This and other important events, both business-related and social, should not be missed. To help you plan your visit the following quick reference guide is designed to complement the Conference Programme and Exhibition Catalogue, where you will find more detailed information.

## THE CONFERENCES

The four conferences run throughout the week, with workshops and short courses (some of which are joint sessions) being run on Sunday 10 and Friday 15, while the conference sessions are scheduled as follows:

- The 36th European Microwave Conference (EuMC 2006) runs from Monday 11 through Thursday 14
- The European Conference on Wireless Technology (ECWT 2006) is on Monday 11 and Tuesday 12
- The first European Microwave Integrated Circuits (EuMIC) conference takes place on Monday 11 through Wednesday 13
- The European Radar Conference (EuRAD 2006) ends the week on Wednesday 13 and Thursday 14.

Registration begins on Saturday 9 September (16.00–19.00) and commences at 07.30 each morning from Sunday 10 to Friday 15. The registration area is located in the main foyer of the G-MEX Centre; delegate bag collection is in the upper foyer of the MICC.

## THE EUROPEAN MICROWAVE CONFERENCE (EuMC)

The exceptionally high number of submissions received from all over the world has resulted in a high quality and comprehensive technical programme. The conference is dedicated to a broad range of high frequency related topics, from materials and technologies to integrated circuits, systems and applications, addressed in all aspects: theory, simulation, design and measurement and is intended as a forum for the presentation and discussion of the most recent advances.

A striking feature this year has been the very high number of submitted papers in the topics of antennas, filters and passive components. Also, the large Networks of Excellence and Integrated Projects funded through the European Union's 6th Framework Programme of research are maturing and producing interesting results. Several of these are relevant to the themes of

the conference and are playing a prominent role though focused sessions, workshops and other activities.

In what is an increase over last year there will be 60 regular oral sessions, including several focused sessions on specific topics, and two poster sessions, located in the European Microwave Exhibition Hall. The concept of EuMW favours the integration of the four component conferences, uniting their respective communities. In this spirit, EuMC features nine joint sessions with its sister conferences: EuMIC, ECWT and EuRAD. In addition, there are various workshops designed to encourage technical exchanges on certain topics, which will take place on Sunday 10 and Friday 15.

## PRIZES AND AWARDS

The EuMC Microwave Prize will be given in recognition of the best contributed paper. Also, the EuMC is awarding the Young Engineer Prize to the young engineer judged to have submitted and presented an outstanding paper at the conference.

## ECWT 2006

This is not only Europe's premier meeting on wireless technology it is also a growing international event, demonstrated by the fact that ECWT received a record number of papers from over 50 counties with a significant proportion of contributors from North America and the Asia Pacific region.

The conference is primarily focused on wireless technology, which was once synonymous with mobile phone systems but has developed much further in recent years. Advances in technology for the phone industry are the enabling force behind many innovations in communications using microwave and mm-wave signals. The evolution from 2G to 3G with the associated shift from voice to data signals has also enabled many more general applications as well as incorporating computer and Internet communications principles. Consequently, this year's

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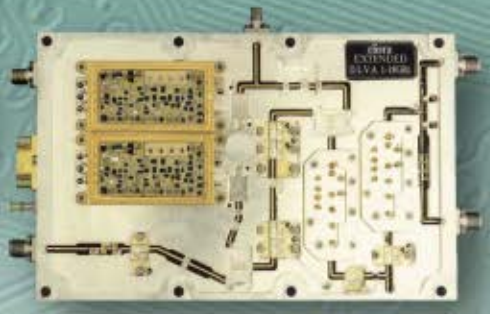

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conference has grown to accommodate these new concepts.

As well as established ECWT topics like antennas and integrated modules, the conference incorporates growing areas such as UWB, WiMAX and HSDPA through to fledgling topics like Cognitive Radio and Ad Hoc Networks. This in conjunction with joint topics in the European Microwave Conference and parallel sessions with the new EuMIC conference offers delegates an intensive update on all the new developments in this industry. They can also discover the latest thinking at the ECWT poster session that will be located in the European Microwave Exhibition Hall on Wednesday.

## EuMIC

The GAAS® Association and the European Microwave Association have worked together to produce this new conference, which maintains the excellent traditions of the former GAAS® symposia but is organised cohesively together with the other conferences within European Microwave Week. As the name suggests this conference will focus on all monolithic microwave integrated circuits whether they are fabricated using silicon, silicon germanium, gallium arsenide, gallium nitride or any other semiconductor material.

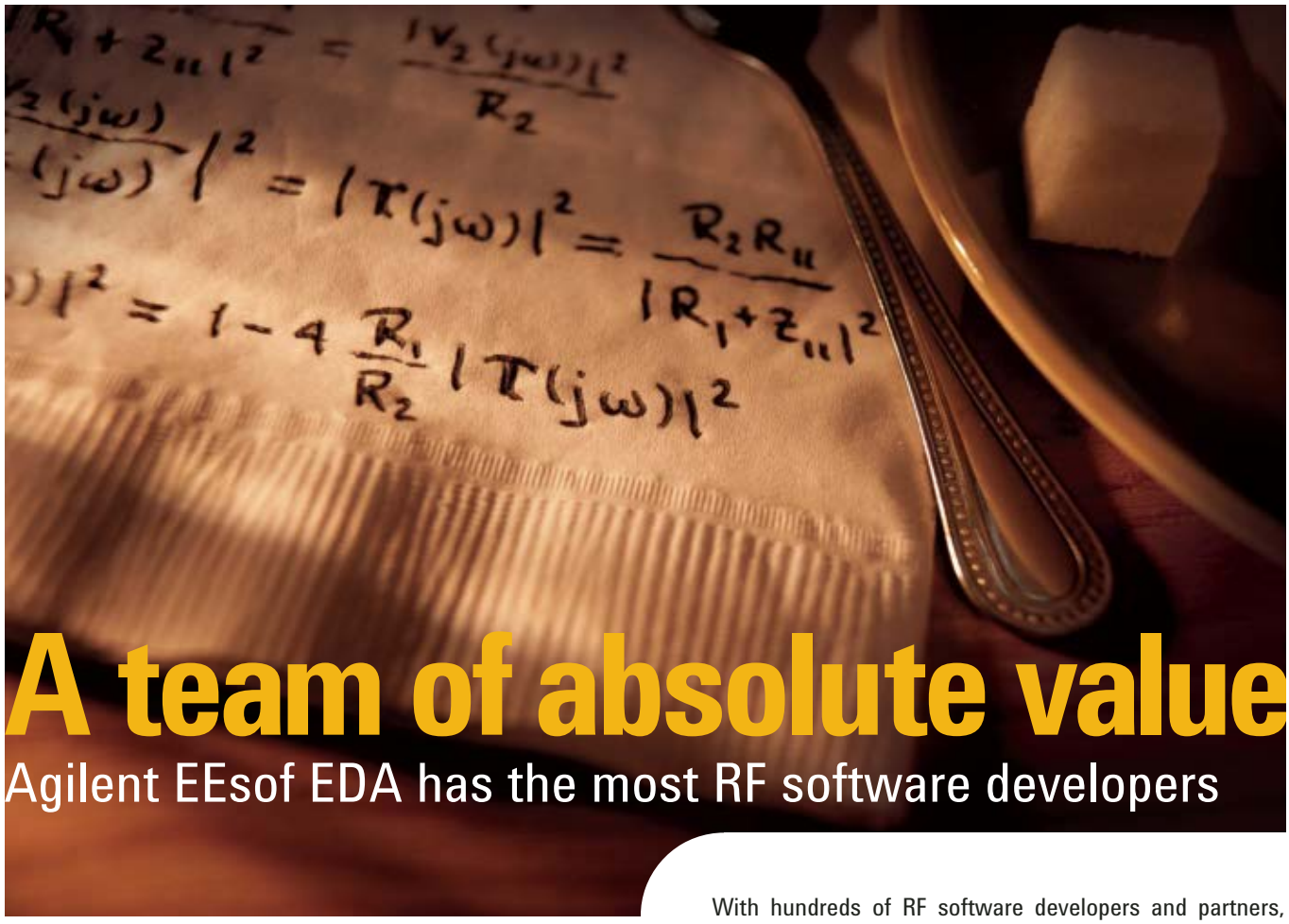
The global involvement and interest in the subjects covered is illustrated by the fact that the technical program, which consists of 85 papers, selected from 189 submitted, represents the work of over 20 countries. Industry and academia participate side by side, which is demonstrated by the three invited speakers at the plenary session which has a definite industrial applications focus.

There are also focused sessions on: characterisation and modeling of microwave power amplifiers within TARGET; MOSFET compact models for RF/microwave applications; advanced technology for transceive modules; and devices and circuits for 100 GHz and beyond, together with a rejuvenated panel session on the future of the GAAS® foundry business. Alongside these technical sessions there is a selection of workshops and a short course, including the ever-popular one-day event on the fundamentals of

microwave power amplifier design. There are half-day workshops on SiGe:C HBT: device, technology and application; RF materials and devices; circuit-level linearization techniques; and nonlinear device noise models and low phase noise oscillator design.

## PRIZES AND AWARDS

To acknowledge the high quality of papers presented at the conference a €3000 prize will be awarded for the best paper and WIN Semiconductors Corp. is sponsoring a €2000 prize for the best student paper. The GAAS® Association will present these winners with a plaque commemorating their achievement, and will be providing three other student fellowships for the 2nd, 3rd and 4th placed student papers.



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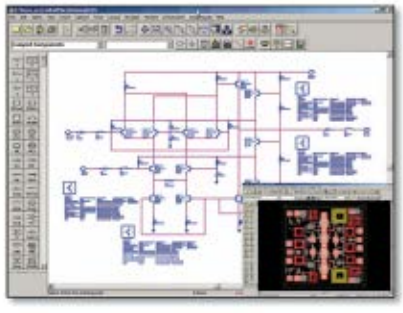

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## EUROPEAN RADAR CONFERENCE (EuRAD)

Right from its inception European Microwave Week has involved radar activities; with the number of radar related papers increasing year by year until in Amsterdam in October 2004, the current series of separate conferences began. That growth has continued with 2006 seeing a substantial conference programme consisting of 55 papers for oral presentation and 35 poster papers. The poster session will be presented in the European Microwave Exhibition Hall on Thursday 14.

Contributions have been received from authors from many countries around the world covering a wide range of topics. Among them are presentations on sparse antenna arrays, remote sensing of the atmosphere, ultra-wideband radar, real-time signal processing, novel antennas, SAR, new transmitter techniques, millimetre-wave radar and netted radars. Also included are workshops on radio astronomy techniques with a visit to Jodrell bank and a workshop on microwave sensors and imaging systems.

## PRIZES AND AWARDS

The Raytheon sponsored Radar Prize of €3000 is awarded to the paper that best advances the state-of-the-art in radar while the Young Engineers Prize of €2000 will go to a young engineer or researcher who has presented an outstanding paper at the conference.

## THE EXHIBITION

For its duration the FREE to enter European Microwave Week Exhibition becomes the hub of the event, housing the conference coffee breaks, poster sessions and hosting the ever popular and invaluable Cyber Café sponsored by CST. Over recent years the exhibition has grown and grown and in 2006 is larger than ever. It has become established as the premier European RF and microwave exhibition, which leading international companies target as a shop window for their latest introductions and innovations.

Over the three days the Central Hall of the G-MEX Centre will be home to companies large and small, established and developing from Europe, North America, Asia and beyond. To find out just who these companies are see the latest exhibitor list, starting on page 54. The common link is that all the companies are actively developing and producing products and services for the RF and microwave industry. Visitors have the chance to find out what is new and under development and talk technical with the experts. That is also the case at the various technical exhibitor workshops and seminars that run alongside the exhibition.

The success of last year's event in Paris is being carried over to Manchester in the guise of the French Pavilion, incorporating the Limoges Pavilion, providing the opportunity for companies, large and small, to exhibit side by side under the Tricolour. To find it look out for the green carpeting.

Also, the advantage of EuMW moving around Europe on a five-year cycle is that small companies from the host country who may not exhibit abroad can get together as a group and showcase their products, so look out for a number of UK companies who have banded together to display their wares.

### *Exhibition Hours*

*Tuesday 12 September:* 09.30–17.30
(followed by the Welcome Reception)
*Wednesday 13 September:*
09.30–17.30
*Thursday 14 September:* 09.30–16.30

## GETTING TO G-MEX/MICC

For most overseas visitors, Manchester Airport provides the most convenient entry to the north of England. It has three terminals and two runways, and approximately 100 airlines serve over 200 destinations worldwide. The airport is located about 10 miles southwest of the city centre, where you'll find the G-MEX/MICC and a plethora of hotels. A frequent 24-hour train service links the airport directly to central Manchester and the airport rail station is adjacent to Terminal 1 International. Direct trains run approximately every ten minutes between Piccadilly Railway Station (in the city centre) and the airport between 5.40 AM–11.30 PM, then approximately every hour through the night. The journey time is 15 to 20 minutes and costs approximately £3. By taxi the journey time is 20 to 30 minutes and costs approximately £12. For more information, visit www.manchesterairport.co.uk.

Manchester is also served by two mainline railway stations, both of which are located in the city centre. Manchester Victoria and Manchester Piccadilly together provide direct rail connections to all major UK cities — the journey time to London is three hours, Birmingham two hours and Edinburgh and Glasgow four hours. Both stations are linked directly by the Metrolink system to GMEX/MICC, which has its own station. If travelling by road, Manchester is ringed by the M60 and ideally close to the UK's extensive motorway network giving easy access to all parts of the country.

## SIGHTSEEING

Organised trips under the Partner Programme include an excursion to the Wedgwood Visitors Centre and Potteries Museum on Tuesday 12 September. Here guests will have the chance to visit the six towns around Stoke-on-Trent, Staffordshire, known as the Potteries and the heart of the British china and porcelain industry, together with the Wedgwood Visitors Centre, which celebrates the work of master potter, Josiah Wedgwood.

On Thursday 14 September there is a trip to the Peak District and Chatsworth House, Derbyshire, one of the most beautiful stately homes in the UK, parts of which date back to the 16th century. This magnificent house is set in a beautiful estate of 35,000 acres, part of which was landscaped by Lancelot (Capability) Brown in the 18th century. The 100 acre gardens were designed by Sir Joseph Paxton.

These trips are subject to the required numbers being achieved. Pre-registration is strongly recommended but there will be the ability to register on site.

## ELECTRICITY

Electricity is supplied at 240 V, 50 Hz.

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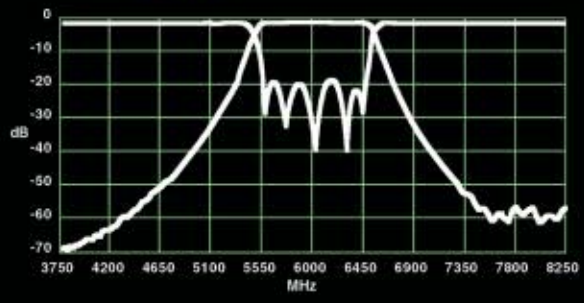


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| Center Frequency Range | 5GHz – 15GHz |
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## HOTEL RESERVATIONS

If you require hotel accommodation during your stay in Manchester, the Hotelzon Resotel booking agency makes reservations at reduced rates in various three, four and five star hotels. This service is offered at no charge. For more information contact the agency at Tel: +44 (0) 20 8722 6920. Alternatively you can access the agency's booking service at www.eumw2006.com, under Accommodation.

## SOCIAL EVENTS

On Monday 11th EuMIC will be celebrating its inception with a Reception and Dinner to be held at the magnificent venue of Manchester Town Hall. The evening will start with a reception in the atmospheric and architecturally stunning Sculpture Hall, with a talk by the honoured guest, the Lord Mayor of Manchester. This will be followed by a four-course meal in the cathedral-like Great Hall and the after dinner speech by David Smith, managing director of Filtronic Compound Semiconductors Ltd., who sponsor the evening.

The EuMW2006 Welcome Reception follows on Tuesday 12 from 18.30–21.00. All registered conference delegates from all four conferences, as well as representatives from the companies participating in the exhibition are invited to this Agilent Technologies, EuMA and Horizon House Publications sponsored event. The Welcome Reception will be held in the Great Northern Hall, which is located in the MICC. There are two entrances; one through the upper foyer and the second through the link from the exhibition. The evening will begin with a champagne reception and a welcome speech by Platinum sponsor Agilent Technologies, who will also present such desirables as iPods and digital cameras in its Prize Draw. Then there is the good food, drink and conversation, of course.

On Wednesday 13 September, the EuMW Gala Dinner will be held at Old Trafford Stadium, the home of Manchester United, which has played host to every level of football over the years including World Cup and European Championship matches. The Gala Dinner will kick off with a drinks reception in Legends, the section of the Manchester United Museum dedicated to the 'greats' of the game, followed by the Gala Dinner in a Hospitality Suite where club honours adorn the walls.

*Please Note*: Should the date of the EuMW Gala Dinner coincide with a football match when the fixtures list is announced during the summer then it will be swapped with the EuMW2006 Welcome Reception.

Last but not least, on Thursday 14 September the EuRAD conference dinner, sponsored by QinetiQ, will be held in the Banqueting Room of the historic Manchester Town Hall, which dates back to Victorian times and is a splendid example of neo-gothic architecture. During the dinner, two prizes, sponsored by Raytheon, will be presented.

## GENERAL INFORMATION

In advance, take time to familiarise yourself with the event and plan your visit by logging onto the show web site at www.eumw2006.com. ■

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# MANCHESTER: WHERE THE PAST MEETS THE PRESENT

Manchester is a fascinating mix of the historical and the modern where the ornate and sometimes austere Victorian architecture sits happily alongside contemporary metallic and glass structures. Its industrial and trading past has been preserved with many of the warehouses, trading halls, factories and civic buildings having been renovated and rejuvenated as luxury hotels, museums, businesses and even domestic dwellings. However, it's 21st century too, with recent regeneration projects transforming areas that suffered from industrial decline into thriving conurbations. Symbols of this modernisation are contemporary buildings such as the Lowry Centre, Imperial War Museum and Urbis, which are stunning feats of architecture that would not be out of place in any major city.

As a major trading port Manchester has been a gateway to the world, attracting trade from far and wide. The legacy is a cosmopolitan city that embraces diverse cultures from Europe, Asia and the Americas as well as the colonies of old. This mix caters to most tastes in food and drink, music and entertainment.

Its offering of places to see and things to do is varied and diverse with two Premier League football teams, two major television companies, three universities, two symphony orchestras, and many small chamber ensembles, numerous theatres, cinemas, museums and galleries. The city is also attractive to shoppers offering the ultimate in choice, from designer chic to antiques and crafts, specialist to second-hand, within compact pedestrian areas that are easy to find your way around. Its credentials as an entertainment capital night and day are unquestionable with a music and club scene of worldwide renown that has been an oasis for pop culture in recent years.

## GETTING AROUND

The city's compact layout, a lot of which is pedestrianised, means most of the hotels, restaurants, pubs, bars and attractions are within easy walking distance of each other.

However, there is a free public bus service, the Metroshuttle, which links all of the city centre railway stations, the main NCP car parks, and many hotels, bus and Metrolink tram stops. It provides three circular routes covering all of the main city centre areas with stops near the G-MEX/MICC and at Piccadilly railway station (Services 1 and 3). The service is frequent, about every five minutes on Service 1 (orange), every 10 minutes on Service 2 (green) and every 10 minutes on Service 3 (purple), which does not operate on Sundays. You can use the free city centre buses to get around,

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Microwave Journal *European Editor*


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hopping on and off as often as you wish. There is also a modern tram service, the Metrolink, which has two stops near G-MEX. It covers parts of the city and extends out to the suburbs.

## MANCHESTER'S DISTRICTS

The city's compact city centre is less than one mile in diameter and within this and the surrounding area are a number of distinct areas that you might want to visit.

### *Peter's Fields*

This is the Conference Quarter and will soon become familiar to visitors of European Microwave Week as it is home to G-MEX/MICC, the event's venue. Directly opposite the centre is the recently built Bridgewater Hall, which has won accolades for its appearance and superb acoustics and is the home to the Hallé Orchestra. Peter's Fields is also the location of the Great Northern shopping and leisure development in the Grade II listed Great Northern Warehouse, with a mixture of retail and leisure venues including bars, cafés and restaurants.

### *Manchester Arndale & Market Street*

Market Street has department stores and independent shops, while the Manchester Arndale dominates the city's central shopping area. It fell victim to an IRA bomb attack in 1996 and has since undergone extensive redevelopment. The site now has over 200 shops on two levels, including fast food outlets and restaurants.

### *Exchange Square & Shambles Square*

Adjacent to Arndale Shopping Centre and the Printworks entertainment complex you'll find Exchange Square, around which is a cluster of hotels. This square has been a focus for redevelopment and in particular the Old Corn Exchange has been transformed into the Triangle Shopping Centre. Leading from the square is Shambles Square, with Sinclair's Oyster Bar and the Old Wellington Inn (see Eating and Drinking), Manchester's oldest pubs, while a recent addition is the modern Urbis, Manchester's Centre for Urban Culture (see Places of Interest).

### *Deansgate, King Street and St Anne's Square*

In what is one of Manchester's most fashionable shopping areas look out for Kendals, a department store with a listed Art Deco façade. St Anne's Square was laid out in Georgian times and is named after the elegant neo-Classical St Ann's Church, which dates back to 1712. At the centre of the square is a memorial commemorating the Boer War and to one side is the Royal Exchange, once the historic Cotton Exchange (see Places of Interest).

### *Chinatown*

One of the most vibrant and colourful areas of the city, Chinatown boasts a plethora of oriental restaurants including Chinese, Korean, Japanese and Thai plus interesting supermarkets and bakeries. The district is bordered by Charlotte Street, Portland Street, Oxford Street and Mosley Street but it is Faulkner Street that is spanned by the magnificent Ming Dynasty Imperial Arch, which was presented to the city by the people of China in 1987. To discover more about Chinese culture visit the Chinese Arts Centre (see Places of Interest).

### *Northern Quarter*

Bounded by Piccadilly to the south and Ancoats to the north, this district has become a hub for the city's artists, designers and musicians. The creative theme continues at Afflecks Palace, which houses more than 50 traders on five floors, with designer fashion, music stores, bars and cafés on offer.

### *Piccadilly*

Known as the main gateway into Manchester and home to the city's main railway station it has been the subject of major regeneration over recent years with Piccadilly Gardens being the main beneficiary. With its impressive fountain and surrounded by popular pubs and bars and hotels it has become a social focal point.

### *Castlefields*

This district to the southwest of the city centre was the site of the settlement that grew up beside the Roman fortress of Mamucium and is regarded as the birthplace of Manchester. Once a wasteland it was designated Britain's first Urban Hertiage Park in the 1980s. Now an attractive waterside district it offers bars, galleries and various tourist attractions including the Castlefield Urban Heritage Centre (see Places of Interest) that houses a reconstruction of the Roman fort. The southern part is centred around water, while the northern part is dominated by the Museum of Science and Industry (see Places of Interest).

### *Salford Quays*

Two miles from Manchester city centre but with easy transport access, Salford Quays epitomises the modern Manchester. Once the industrial and dilapidated docks area it has been part of one of the largest regeneration schemes in the UK and is now known as Greater Manchester's Waterfront. It has been transformed into a cultural and social hub and features some of the city's most spectacular modern buildings in The Lowry and the Imperial War Museum (see Places of Interest). There are also hotels, theatres, cafés, restaurants, bars and a shopping mall not to mention its close proximity to Old Trafford, the home of the Manchester United Football Club.

## PLACES OF INTEREST

Manchester has a lot to see. Alongside the cultural, historic and contemporary buildings there is a lot to interest the engineer, particularly the Museum of Science and Industry and the Imperial War Museum.

*Photo courtesy of Jan Chlebik.*

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### *Museum of Science and Industry*

The museum's 15 galleries are sited in five historic buildings, including the world's first railway warehouse and passenger railway station on a 7½ acre site. They are home to exhibitions, hands-on galleries, historic working machinery and special exhibitions. Look out for the intricately glazed Victorian market hall that holds the planes that made flying history and also a recreation of Stephenson's Planet.

### *Imperial War Museum*

Located in Salford Quays the modern building is an attraction in itself; the design is a dramatic and symbolic sculpture, with three linked buildings shaped as shards from a broken globe, designated as air, earth and water and representing three battlegrounds of war, to 'reflect the way war has devastated the world.' The IWM utilises many new and innovative modern exhibition design techniques and the very latest interactive technologies but also has more traditional displays of war memorabilia. There is also an extensive art collection with paintings and drawings commissioned during the two World Wars, as well as collections of photographs, film and other period documentation.

### *The Lowry*

Close to the IWM and an equally stunning modern building, The Lowry houses the works of Manchester's best known artist LS Lowry, famous for his 'match stick' figures, but is much more. It has two theatres, galleries showing the works of artists of regional, national and international standing, and cafés and restaurants.

### *Urbis*

Manchester's Centre for Urban Culture is a dramatic glass building rising high above the centre of the city and is worth a visit just to take the one minute sky glide in the MEN Glass Elevator to savour the views. Inside the interactive exhibits lead you on a journey exploring life in different cities around the world.

### *Bridgewater Hall*

Still on the contemporary theme this prestigious international concert hall should attract even non-music lovers just for its architecture, especially as it is very close to G-MEX/MICC. It is home to the Hallé Orchestra and features a magnificent Marcussen pipe organ. At the time of EuMW it will be celebrating its 10-year anniversary.

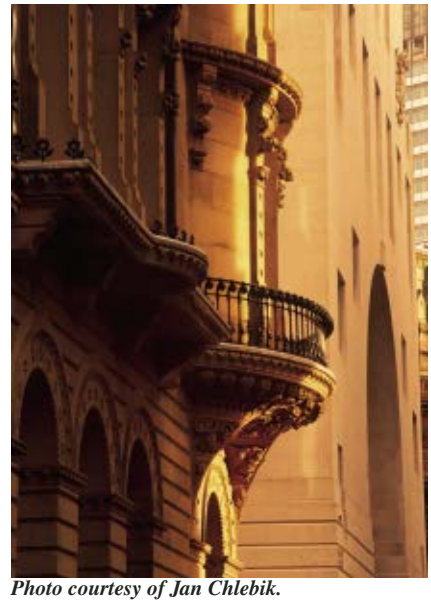

*Photo courtesy of Jan Chlebik.*

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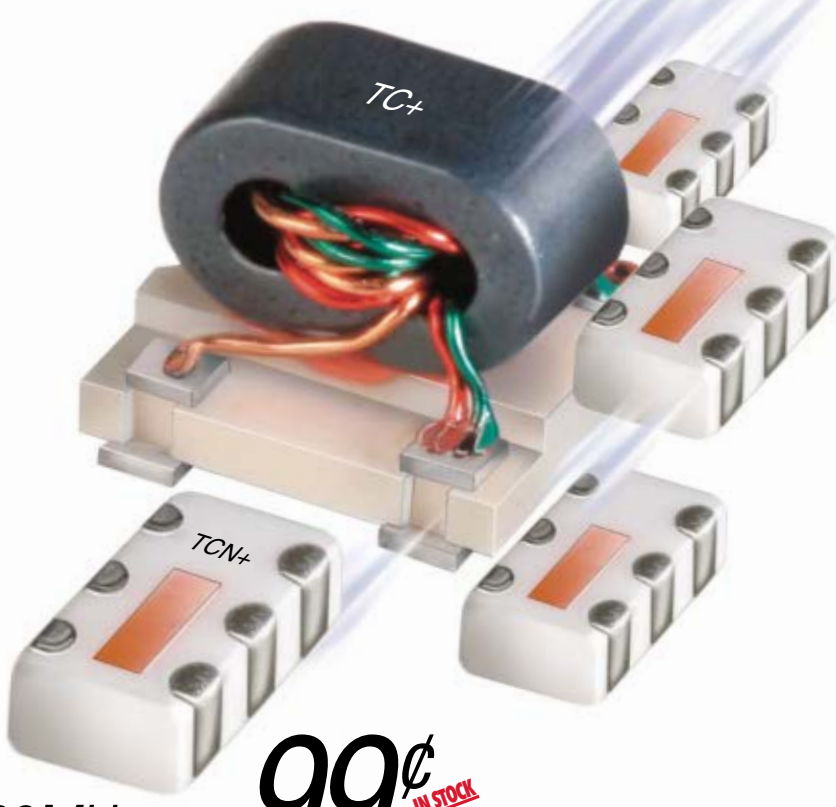


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| TC4-1T+ | 4 | A | 0.5-300 | 1.19 |
| TC4-1W+ | 4 | A | 3-800 | 1.19 |
| TC4-25+ | 4 | H | 500-2500 | 1.09 |
| TC4-6T+ | 4 | A | 1.5-600 | 1.19 |
| TC8-1+ | 8 | A | 2-500 | 1.19 |
| TC9-1+ | 9 | A | 2-200 | 1.29 |
| TC16-1T+ | 16 | A | 20-300 | 1.59 |
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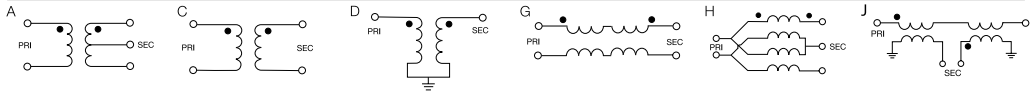

*Photo courtesy of Joel Fildes.*

### *Manchester Town Hall*

One of the city's finest historic buildings, this striking Victorian Gothic style edifice has magnificent Ford Maddox Brown murals, which portray Victorian ideas depicting science, invention, education, trade and the textile industry.

### *Manchester Cathedral*

The cathedral boasts some of the finest medieval carving in Europe and a whole wall of twentieth-century stained glass. Next door the stunning Visitor Centre houses a hi-tech, interactive exhibition about the cathedral and its links with the city, community and the wider world.



### *Royal Exchange*

Bridging the old and new the once historic Cotton Exchange is now home to the Royal Exchange Theatre, the world's largest theatre in-the-round. As well as the theatre, this vast, stylish space under three impressive domes houses gift shops, restaurants, antiques gallery, specialist shops and fashion on three floors.

### *Chinese Arts Centre*

This flagship centre for Chinese arts in Britain aims to develop an infrastructure to allow Chinese arts, and especially British Chinese artists, to flourish. It contains a gallery which features the best of British and international Chinese art, an artist residency studio, an education suite, resource area, offices, shop and tea house.

### *Castlefield Urban Heritage Park*

Britain's first Urban Heritage Park contains a wealth of Manchester's industrial heritage, including railway viaducts, canal systems and museums as well as tourist attractions such as waterside pubs, pleasant walks, boat trips and frequent events in the Outdoor Arena. The Castlefield Visitors Centre on Liverpool Road provides information and guidance to visitors and houses a small permanent exhibition on the history and development of the area.

## EATING AND DRINKING

Manchester offers food and drink for all tastes and all pockets and here is just a selection. Phone numbers are given but if calling from outside the UK use the International Dialling Code +44 and leave off the first zero.

## PUBS

No visit to the UK is complete without a visit to a traditional pub. Manchester has too many to list but here is a selection.

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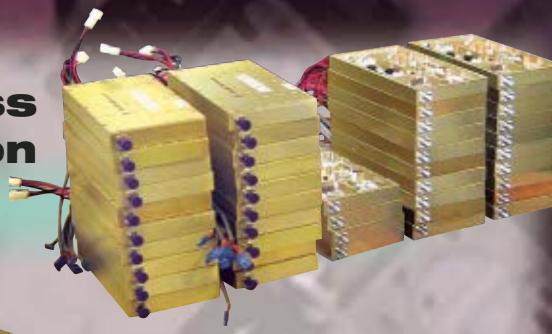
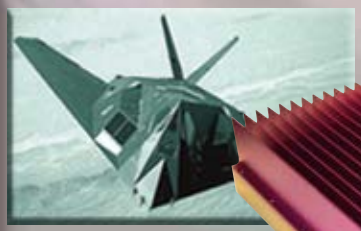
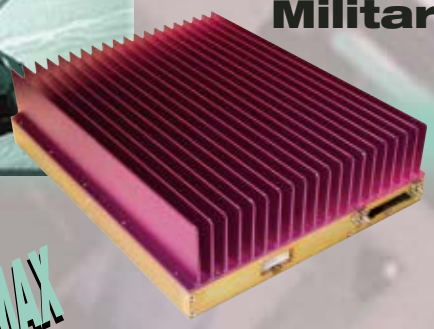
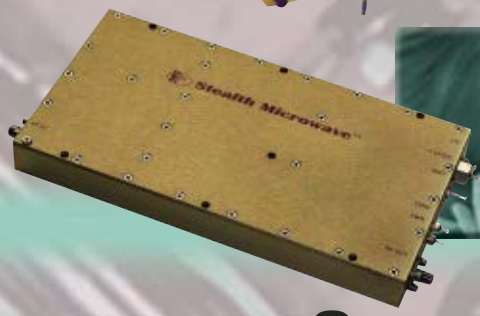




Military





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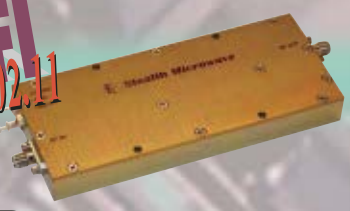
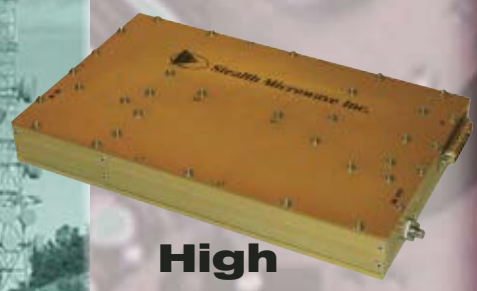


Low Power



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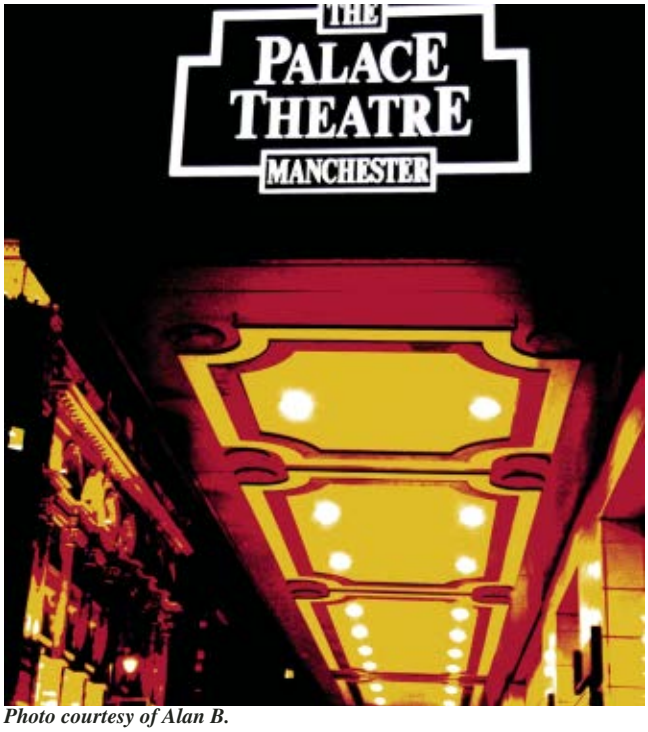


*Photo courtesy of Alan B.*

### *Old Wellington Inn and Restaurant*

Claiming to be the oldest pub in Manchester it dates back to 1552. As well as the ground floor bar it also boasts an all day restaurant.

4 Cathedral Gates, Tel: 0161 830 1440

### *Bull's Head*

The character, including the stained glass, has been retained during sympathetic refurbishment. As well as good beers it is famous for its Sunday roasts.

84 London Road, Tel: 0161 236 1724

### *Peveril of the Peak*

Immediately next door to the Bridgewater Hall this traditional Manchester pub dates from around the early 1800s. It has a Games Room where you can play darts and table football.

127 Great Bridgewater Street, Tel: 0161 236 6364

### *The Marble Arch*

As well as the traditional real ales this pub is worth a visit for its ornate interiors, with decorative tiles and floor mosaics.

79 Rochdale Road, Tel: 0161 832 5914

## EATING OUT

## TRADITIONAL BRITISH

### *39 Steps*

The onus is on fresh produce and fish dishes but save some room for the desserts when visiting this basement restaurant.

39 South King Street, Tel: 0161 833 2432

### *The Lincoln*

With its offering of traditional and modern British food this restaurant has earned a good reputation in a relatively short time.

1 Lincoln Square, Tel: 0161 834 9000.

### *Livebait*

As the name suggests the emphasis here is on fresh fish and shellfish. The menu can be exotic but there is always good old British fish and chips available.

22 Lloyd Street,
Albert Square, Tel: 0161 817 4110

## HOTEL RESTAURANTS

### *Robbies Restaurant and Bar*

With a Scottish theme you'll find a good selection of whiskies alongside cocktails in the bar and good quality food, especially steaks in the restaurant.

The Renaissance Hotel,
Blackfriars Street, Tel: 0161 831 6000

### *Opus One*

The lavish surroundings of red glass, gold and black set the tone for culinary indulgence for British food with a twist.

Radisson Edwardian Hotel,
Peter Street, Tel: 0161 835 8904

### *The Waterhouse*

Another example of sympathetic refurbishment this eatery has a modern flavour with a regularly changing a la carte menu and fine wine list.

The Palace Hotel, Oxford Street, Tel: 0161 236 9999

## MODERN EUROPEAN

### *Beluga*

In the heart of the city this restaurant offers stylish and elegant modern décor with booths that can accommodate intimate couples or larger parties.

2 Mount Street,
Tel: 0161 833 3339

### *Establishment*

This award winning restaurant is a former Grade II listed former banking hall where the 200 year old marbled interior has undergone a dramatic and stunning facelift, which is matched by the quality of the food and wine.

43-45 Spring Gardens, Tel: 0161 839 6300

## FRENCH

### *Le Mont*

Hit the heights in this restaurant located on the upper floors of Urbis (see Places of Interest). The cuisine is French with the menu in French and English. There is an extensive wine list.

Cathedral Gardens,
Tel: 0161 605 8282

### *Brasserie St Pierre*

If you have never eaten French food in Edwardian surroundings then try this popular and smart brasserie.

57 Princess Street, Tel: 0161 228 0231

### *Le Petit Blanc*

Another brasserie, this one has been opened by famous chef, Raymond Blanc, and is small but perfectly formed.

55 King Street, off Chapel Walks,
Tel: 0161 832 1000


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### *Le Bouchon*

Classic French cuisine in a small restaurant with a great atmosphere.
63 Bridge Street,
Tel: 0161 832 9393

## ITALIAN

### *Croma*

Offers pizza with pizzazz in trendy open surroundings of glass and steel. The salads and pasta dishes are also worth a look.
Clarence Street,
Tel: 0161 237 9799

### *Cocotoo's*

This converted railway arch is tastefully decorated with Michelangelo's Sistine Chapel paintings over the bar.
57 Whitworth St West,
Tel: 0161 237 5458



## CHINESE

### *Tai Pan*

They don't have to go far for their ingredients as it located above a Chinese supermarket. It is inexpensive yet good quality.
Brunswick House, 81–97 Upper Brook Street, Tel: 0161 273 2798

### *Pearl City*

One of Manchester's oldest established Chinese restaurants offers classical Cantonese dishes and dim sum.
33 George Street, Chinatown,
Tel: 0161 228 7683

### *Yang Sing*

Risen from the ashes of a fire a few years ago the restaurant produces good food in an exquisite setting. Look out for special banquet meals.
34 Princess Street, Chinatown,
Tel: 0161 236 2200

## INDIAN

There are good Indian restaurants in central Manchester. However, the true enthusiast should venture to Rusholme, a couple of miles outside of the centre and the famous Curry Mile. This strip of curry houses is vast and varied and here is just a selection.

### *Darbar*

The restaurant's name means Kings Court and every effort is made to make the food and atmosphere fit for a king.
65–67 Wilmslow Road, Rusholme,
Tel: 0161 2244 392

### *King Cobra*

As well as traditional food there is also the unique opportunity to sample exquisite Sri Lankan cuisine.
Tel: 0161 248 9999

*Photo courtesy of David Oats.*

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COVER FEATURE ARTICLE MICROWAVE JOURNAL, Sept. 2002


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*" Fast CAD and Optimization of Waveguide Components and Aperture Antennas by Hybrid MM/FE/MoM/FD Methods - State-of-the-Art and Recent Advances." (Invited Paper)* IEEE TRANS. MTT-52, p.292, Jan. 2004

WASP-NET achieves the high-speed, full-wave optimization of rectangular, circular, ridged, coaxial, elliptical waveguide components, horns, reflectors, slot arrays, combline, interdigital, LTCC, dielectric resonator filters / diplexers

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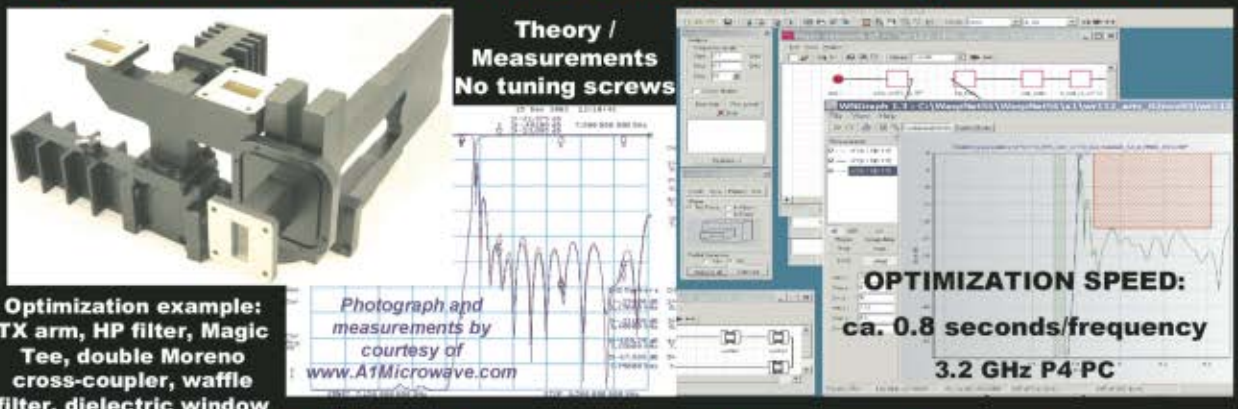


**Optimization example: TX arm, HP filter, Magic Tee, double Moreno cross-coupler, waffle filter, dielectric window**

## MiG Microwave Innovation Group


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In cooperation with the University of Bremen, Germany


**Visit us at EuMW 2006, Manchester, UK, Booth 523**

*Photo courtesy of Chris Harrison.*

### *Sanam Sweet House and Restaurant*

One the oldest establishments on Wilmslow Road this curry house is completely Hilal, so no alcohol.
145-151 Wilmslow Road, Rusholme, Tel: 0161 2248 824

## THE UNUSUAL

### *Red Café*

At the home of Manchester United this is a sports café with a video screen and football memorabilia. The food leans towards burgers, baguettes and salads.
Manchester United, Sir Matt Busby Way,
Old Trafford, Tel: 0161 868 8303



### *Copacabana*

As well as the Latin American cuisine there is also the chance to savour and join in with the nightly salsa classes.
Dale Street, Tel: 0161 237 3441.

### *Matt and Phreds*

Jazz is on the menu here with a stage where a jazz band accompanies the food, which is as varied as the music.
64 Tib Street, Tel: 0161 831 7002

## A SELECTION OF TASTES

### *The Cedar Tree*

This award winning Lebanese restaurant offers traditional food incorporating a wide variety of exotic fresh ingredients.
69 Thomas Street, Tel: 0161 834 5016

### *Koreana*

The modest entrance belies the expansive and stylish basement dining space where local Asians flock to savour true Korean food.
40A King Street West

### *New Samsi*

Exotic and adventurous Japanese food brings a taste of the orient to what was an historic cotton warehouse.
38 Whitworth Street,
Tel: 0161 279 0022

This is just a fraction of what Manchester has to offer. Use this guide to make the most of any spare time you have at European Microwave Week and enjoy your visit. ■

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# Broadband Amplifiers by AML Communications

To Order Call: (805)388-1345 ext. 203

| Model | Frequency (GHz) | Gain (dB) | Flatness (dB) max | NF (dB) max | P1dB (dBm) min | VSWR (In/Out) | DC Current @ +12/+15VDC |
|---|---|---|---|---|---|---|---|
| **Broadband Low Noise Amplifiers** | | | | | | | |
| AML016L2802 | 0.1 – 6.0 | 28 | ±1.25 | 1.3* | +7 | 2.0:1 | 190 |
| AML48L3001 | 4.0 – 8.0 | 30 | ±1.0 | 1.2 | +10 | 1.8:1 | 150 |
| AML412L3002 | 4.0 – 12.0 | 30 | ±1.5 | 1.5 | +10 | 1.8:1 | 150 |
| AML218L0901 | 2.0 – 18.0 | 9 | ±1.0 | 2.2 | +5 | 2.5:1 | 60 |
| AML0518L1601-LN | 0.5 – 18.0 | 16 | ±1.0 | 2.7 | +8 | 2.2:1 | 100 |
| AML0126L2202 | 0.1 – 26.5 | 22 | ±2.25 | 3.5* | +8 | 2.2:1 | 170 |
| AML1226L3301 | 12.0 – 26.5 | 33 | ±2.0 | 2.8 | +8 | 2.5:1 | 200 |
| **Broadband Medium Power Amplifiers** | | | | | | | |
| AML0016P2001 | 0.01 – 6.0 | 21 | ±1.25 | 3.2* | +23* | 2.0:1 | 480 |
| AML26P3001-2W | 2.0 – 6.0 | 28 | ±2.5 | 6 | +33 | 1.8:1 | 1500 |
| AML28P3002-2W | 2.0 – 8.0 | 30 | ±2.0 | 5.5 | +33 | 2.0:1 | 2000 |
| AML218P3203 | 2.0 – 18.0 | 32 | ±2.5 | 4 | +25 | 2.0:1 | 450 |
| AML618P3502-2W | 6.0 – 18.0 | 35 | ±2.5 | 4 | +33 | 2.0:1 | 1850 |
| **Narrow Band Low Noise Amplifiers** | | | | | | | |
| AML23L2801 | 2.8 – 3.1 | 28 | ±0.75 | 0.7 | +10 | 1.8:1 | 150 |
| AML1414L2401 | 14.0 – 14.5 | 24 | ±0.75 | 1.5 | +10 | 1.5:1 | 130 |
| AML1718L2401 | 17.0 – 18.0 | 24 | ±0.75 | 1.6 | +10 | 1.8:1 | 150 |

| Low Phase Noise Amplifiers | | | | Phase noise (dBc/Hz) at offset | | | |
|---|---|---|---|---|---|---|---|
| Part Number | Frequency (GHz) | Gain (dB) | Output Power (dBm) | 100Hz | 1KHz | 10KHz | 100KHz |
| AML811PN0908 | 8.5 – 11.0 | 9 | 17 | -154 | -159 | -167 | -170 |
| AML811PN1808 | 8.5 – 11.0 | 18 | 18 | -152.5 | -157.5 | -165.5 | -168 |
| AML811PN1508 | 8.5 – 11.0 | 15 | 28 | -145.5 | -153.5 | -158.5 | -164.5 |
| AML26PN0904 | 2.0 – 6.0 | 9 | 20 | -150 | -165 | -165 | -178 |
| AML26PN1201 | 2.0 – 6.0 | 11 | 15 | -155 | -160 | -160 | -175 |

| High Dynamic Range Amplifiers | | | | | |
|---|---|---|---|---|---|
| Part Number | Frequency (MHz) | Gain (dB) | P1dB (dBm) | OIP3 (dBm) | DC |
| AR01003251X | 2 – 32 | 21 | 32 | 52 | +28V @ 470mA |
| AFL30040125 | 50 – 500 | 23 | 28 | 53 | +28V @ 700mA |
| BP60070024X | 20 – 2000 | 32 | 30 | 43 | +15V @ 1100mA |

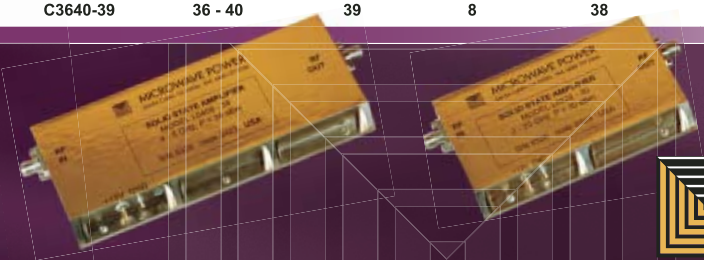
*Above 500MHz.

# Power Amplifiers by Microwave Power

To Order Call: (408)727-6666 ext. 42

| Model | Frequency (GHz) | Psat (dBm) | Psat (W) | P1dB (dBm) | Gain (dB) | DC Current(A) @ +12V or +15V |
|---|---|---|---|---|---|---|
| **Broadband Microwave Power Amplifiers** | | | | | | |
| L0104-43 | 1 - 4 | 42.5 | 17.8 | 41.5 | 45 | 14 |
| L0204-44 | 2 - 4 | 44 | 25 | 42.5 | 45 | 14 |
| L0206-40 | 2 - 6 | 40 | 10 | 38.5 | 40 | 8.5 |
| L0208-41 | 2 - 8 | 41 | 12 | 40 | 40 | 17 |
| L0218-32 | 2 - 18 | 32 | 1.4 | 31 | 35 | 5 |
| L0408-43 | 4 - 8 | 43 | 20 | 41.5 | 45 | 17 |
| L0618-43 | 6 - 18 | 43 | 20 | 41.5 | 45 | 22 |
| L0812-46 | 8 - 12 | 46 | 40 | 45 | 45 | 28 |
| **Millimeter-Wave Power Amplifiers** | | | | | | |
| L1826-34 | 18 - 26 | 34 | 2.5 | 33 | 35 | 4 |
| L1840-27 | 18 - 40 | 27 | 0.5 | 26 | 30 | 2 |
| L2240-28 | 22 - 40 | 28.5 | 0.7 | 27 | 30 | 3 |
| L2630-39 | 26 - 30 | 39 | 8.0 | 38 | 40 | 15 |
| L2632-37 | 26 - 32 | 37 | 5.0 | 36 | 38 | 10 |
| L2640-31 | 26 - 40 | 31 | 1.2 | 30 | 30 | 5 |
| L3040-33 | 30 - 40 | 33 | 2.0 | 32 | 33 | 9 |
| L3337-36 | 33 - 37 | 36 | 4.0 | 35 | 40 | 12 |
| L3640-36 | 36 - 40 | 36 | 4.0 | 35 | 40 | 10 |

| High-Power Rack Mount Amplifiers | | | | | | |
|---|---|---|---|---|---|---|
| Model | Frequency (GHz) | Psat (dBm) | Psat (W) | P1dB (dBm) | Pac (kW) | Height (in) |
| C071077-52 | 7.1 - 7.7 | 52.5 | 170 | 51.5 | 1.8 | 10.25 |
| C090105-50 | 9 - 10.5 | 50 | 100 | 49 | 1 | 8.75 |
| C140145-50 | 14 - 14.5 | 50.5 | 110 | 49.5 | 2 | 10.25 |
| C1416-46 | 14 - 16 | 46 | 40 | 45 | 0.35 | 5.25 |
| C1820-43 | 18 - 20 | 43 | 20 | 41.5 | 0.25 | 5.25 |
| C2326-40 | 23 - 26 | 40 | 10 | 39 | 0.25 | 5.25 |
| C2630-45 | 26 - 30 | 45 | 30 | 44 | 0.45 | 5.25 |
| C3236-40 | 32 - 36 | 40 | 10 | 39 | 0.25 | 5.25 |
| C3640-39 | 36 - 40 | 39 | 8 | 38 | 0.24 | 5.25 |



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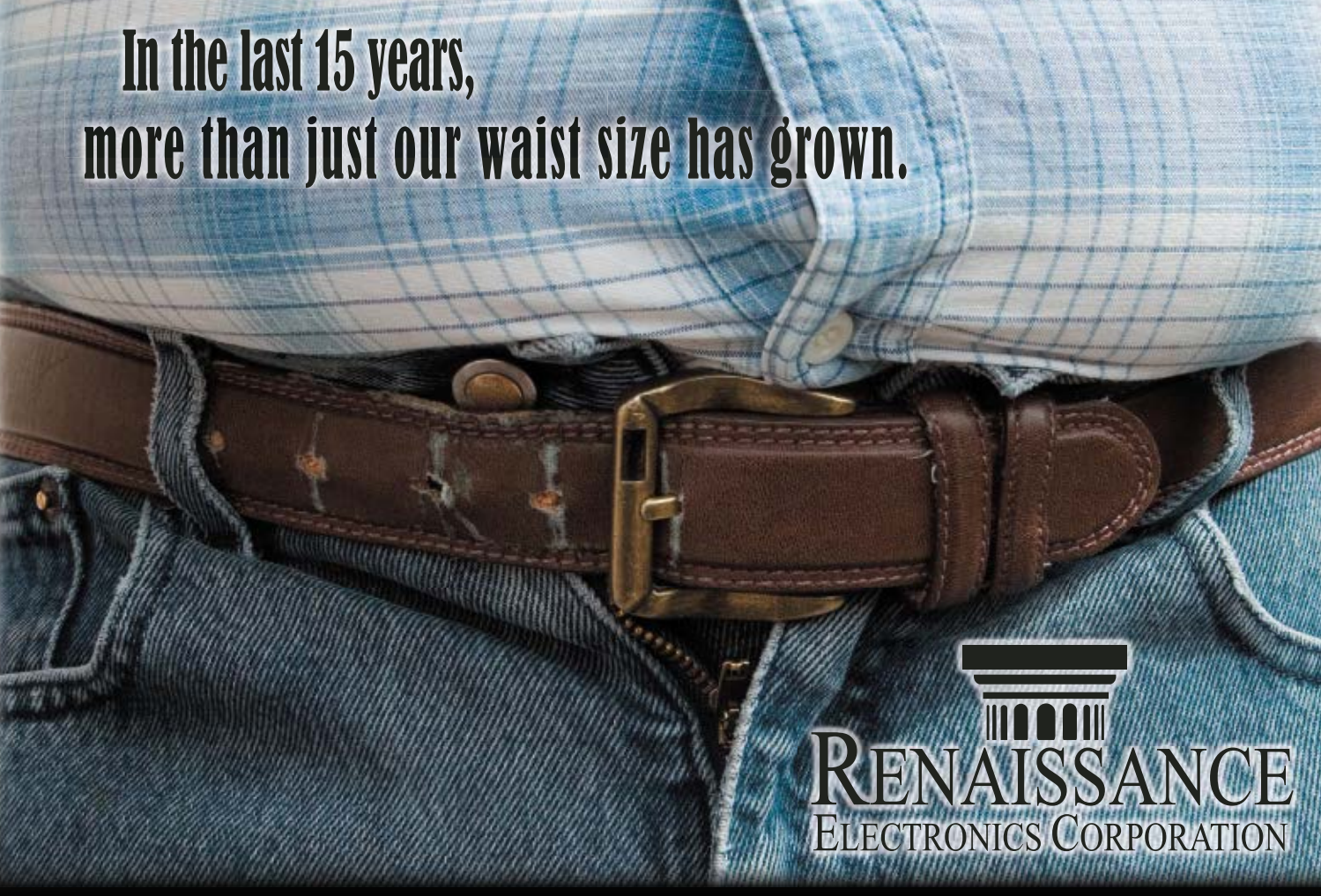


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### LOW NOISE OCTAVE BAND AMPLIFIERS

| Model No. | Frequency GHz | Gain dB MIN | Noise Figure dB | Output Power (dBm) MIN @ P1 dB Comp PT | 3rd Order ICP dBm TYP | VSWR MAX |
|---|---|---|---|---|---|---|
| CA01-2110 | 0.5 - 1.0 | 28 | 1.0 MAX, 0.7 TYP | +10 | +20 | 2.0:1 |
| CA12-2110 | 1.0 - 2.0 | 30 | 1.0 MAX, 0.7 TYP | +10 | +20 | 2.0:1 |
| CA24-2110 | 2.0 - 4.0 | 32 | 1.2 MAX, 1.0 TYP | +10 | +20 | 2.0:1 |
| CA48-2110 | 4.0 - 8.0 | 32 | 1.4 MAX, 1.2 TYP | +10 | +20 | 2.0:1 |
| CA812-3110 | 8.0 - 12.0 | 27 | 1.8 MAX, 1.6 TYP | +10 | +20 | 2.0:1 |
| CA1218-4110 | 12.0 - 18.0 | 25 | 2.0 MAX, 1.8 TYP | +10 | +20 | 2.0:1 |

### ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

| Model No. | Frequency GHz | Gain dB MIN | Noise Figure dB | Output Power (dBm) MIN @ P1 dB Comp PT | 3rd Order ICP dBm TYP | VSWR MAX |
|---|---|---|---|---|---|---|
| CA0102-3110 | 0.1 - 2.0 | 28 | 2.0 Max, 1.5 Typ | +10 | +20 | 2.0:1 |
| CA0106-3110 | 0.1 - 6.0 | 28 | 2.0 Max, 1.5 Typ | +10 | +20 | 2.0:1 |
| CA0108-3110 | 0.1 - 8.0 | 26 | 2.2 Max, 1.8 Typ | +10 | +20 | 2.0:1 |
| CA0108-4112 | 0.1 - 8.0 | 32 | 3.0 MAX, 1.8 Typ | +22 | +32 | 2.0:1 |
| CA26-3110 | 2.0 - 6.0 | 26 | 2.0 MAX, 1.5 TYP | +10 | +20 | 2.0:1 |
| CA26-3113 | 2.0 - 6.0 | 28 | 4.0 MAX, 3.0 TYP | +27 | +37 | 2.0:1 |
| CA26-4114 | 2.0 - 6.0 | 22 | 5.0 MAX, 3.5 TYP | +30 | +40 | 2.0:1 |
| CA618-4112 | 6.0 - 18.0 | 25 | 5.0 MAX, 3.5 TYP | +23 | +33 | 2.0:1 |
| CA618-5113 | 6.0 - 18.0 | 24 | 5.0 MAX, 3.5 TYP | +27 | +37 | 2.0:1 |
| CA618-6114 | 6.0 - 18.0 | 35 | 5.0 MAX, 3.5 TYP | +30 | +40 | 2.0:1 |
| CA618-6115 | 6.0 - 18.0 | 35 | 6.0 MAX, 3.5 TYP | +32 | +41 | 2.0:1 |
| CA218-4110 | 2.0 - 18.0 | 30 | 5.0 MAX, 3.5 TYP | +20 | +30 | 2.0:1 |
| CA218-4112 | 2.0 - 18.0 | 29 | 5.0 MAX, 3.5 TYP | +24 | +34 | 2.0:1 |
| CA218-4113 | 2.0 - 18.0 | 29 | 5.0 MAX, 3.5 TYP | +27 | +37 | 2.0:1 |

### NARROW BAND AMPLIFIERS

| Model No. | Frequency GHz | Gain dB MIN | Noise Figure dB | Output Power (dBm) MIN @ P1 dB Comp PT | 3rd Order ICP dBm TYP | VSWR MAX |
|---|---|---|---|---|---|---|
| LOW NOISE: | | | | | | |
| CA01-2110 | 0.4 - 0.5 | 28 | 0.75 MAX, 0.45 TYP | +10 | +20 | 2.0:1 |
| CA01-2112 | 0.8 - 1.0 | 28 | 0.75 MAX, 0.45 TYP | +10 | +20 | 2.0:1 |
| CA12-3116 | 1.2 - 1.6 | 25 | 0.75 MAX, 0.5 TYP | +10 | +20 | 2.0:1 |
| CA23-3110 | 2.2 - 2.4 | 30 | 0.75 MAX, 0.5 TYP | +10 | +20 | 2.0:1 |
| CA23-3110 | 2.7 - 2.9 | 29 | 0.7 MAX, 0.5 TYP | +10 | +20 | 2.0:1 |
| CA34-2110 | 3.7 - 4.2 | 28 | 1.0 MAX, 0.5 TYP | +10 | +20 | 2.0:1 |
| CA56-3110 | 5.4 - 5.9 | 40 | 1.0 MAX, 0.5 TYP | +10 | +20 | 2.0:1 |
| CA78-4110 | 7.25 - 7.75 | 32 | 1.2 MAX, 1.0 TYP | +10 | +20 | 2.0:1 |
| CA910-3110 | 9.0 - 10.6 | 25 | 1.4 MAX, 1.2 TYP | +10 | +20 | 2.0:1 |
| CA1315-3110 | 13.75 - 15.4 | 25 | 1.6 MAX, 1.5 TYP | +10 | +20 | 2.0:1 |
| CA1819-4110 | 17.7 - 18.3 | 20 | 2.0 MAX, 1.8 TYP | +10 | +20 | 2.0:1 |
| MEDIUM POWER: | | | | | | |
| CA12-3114 | 1.35 - 1.85 | 30 | 4.0 MAX, 3.0 TYP | +33 | +41 | 2.0:1 |
| CA23-4110 | 2.7 - 2.9 | 32 | 4.0 MAX, 3.0 TYP | +33 | +41 | 2.0:1 |
| CA34-6116 | 3.1 - 3.5 | 40 | 4.5 MAX, 3.5 TYP | +35 | +43 | 2.0:1 |
| CA56-5114 | 5.9 - 6.4 | 30 | 5.0 MAX, 4.0 TYP | +30 | +40 | 2.0:1 |
| CA812-6116 | 8.0 - 12.0 | 30 | 5.0 MAX, 4.0 TYP | +33 | +41 | 2.0:1 |
| CA1213-7110 | 12.2 - 13.25 | 28 | 6.0 MAX, 5.5 TYP | +33 | +42 | 2.0:1 |
| CA1218-5116 | 12.0 - 18.0 | 35 | 6.0 MAX, 5.0 TYP | +30 | +40 | 2.0:1 |
| CA1415-7110 | 14.0 - 15.0 | 30 | 5.0 MAX, 4.0 TYP | +30 | +40 | 2.0:1 |
| CA1722-4110 | 17.0 - 22.0 | 25 | 3.5 MAX, 2.8 TYP | +21 | +31 | 2.0:1 |
| CA1718-4110 | 17.7 - 18.1 | 25 | 5.0 MAX, 4.5 TYP | +27 | +37 | 2.0:1 |

### COMPETITIVE PRICING OFFERED

| Model No. | Frequency GHz | Gain dB MIN | Noise Figure dB | Output Power (dBm) MIN @ P1 dB Comp PT | Unit Price Qty 1-9 $US |
|---|---|---|---|---|---|
| CA12-A02 | 1.0-2.0 | 26 | 1.6 | +10 | $395 |
| CA24-A02 | 2.0-4.0 | 26 | 1.8 | +10 | $395 |
| CA48-A02 | 4.0-8.0 | 24 | 2.0 | +10 | $395 |
| CA812-A02 | 8.0-12.0 | 22 | 2.5 | +10 | $395 |
| CA1218-A02 | 12.0-18.0 | 16 | 3.5 | +10 | $395 |

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## Northrop Grumman Announces Team for Homeland Security SBInet Bid

Northrop Grumman Corp. has named its team of partner companies for the Department of Homeland Security (DHS) Secure Border Initiative Net (SBInet) competition. SBInet is a six-year, $2 B program that will provide the DHS's Customs and Border Protection directorate with a comprehensive border-protection solution comprised of integrated technologies, infrastructure, rapid-response capability and personnel. Northrop Grumman is leading a team comprised of seven large partners, solution providers and a host of small businesses as well as partners providing community outreach. Northrop Grumman's seven large partners include: Anteon International Corp. and SRA International, Fairfax, VA; BearingPoint Inc., McLean, VA; L. Robert Kimball & Associates, Ebensburg, PA; HNTB Corp., Kansas City, MO; L3 Communications Titan Group, San Diego, CA; and General Dynamics, Falls Church, VA. Northrop Grumman solution providers include: EMD Corp., Hopkinton, MA; ESRI, Redlands, CA; Hughes Network Systems LLC, Germantown, MD; Motorola Inc., Schaumberg, IL; Sprint/Nextel, Reston, VA; Oracle Corp., Redwood Shores, CA; Identix, Minnetonka, MI; and Nortel, Brampton, Ontario, Canada. "Northrop Grumman has extensive experience as a lead systems integrator delivering large-scale, mission-critical homeland security solutions for the federal government, including the Department of Homeland Security and law enforcement agencies," said Wood Parker, president of Northrop Grumman Information Technology's Intelligence Group. "Together with our industry partners, we can deliver a comprehensive solution, working closely with the government to enable stronger border security, deter illegal border crossing and ultimately help achieve DHS's goal of operational control of our nation's borders." The Department of Homeland Security is scheduled to award the SBInet contract in September 2006.

## DARPA Selects Raytheon to Develop Its Secure Enterprise Network

Raytheon Co. will develop and deploy a new communications network for the Defense Advanced Research Project Agency (DARPA). The $14 M contract calls for Raytheon to build DARPA's Secure Enterprise Network (DSEN), a state-of-the-art, secure network, and to provide support to DARPA's existing classified systems. Raytheon was selected based on the company's outstanding performance scores in providing similar solutions for the last five years to customers in the classified community. The award, which has a potential value of $57 M, also includes maintenance and transition of DARPA's existing networks to meet future requirements. Raytheon's DSEN solution is based on its Compartmented High Assurance Information Network (CHAIN) architecture. This accreditable, service-oriented architecture provides a secure, compartmented Microsoft Windows-based environment — a user-friendly environment familiar to today's countless personal computer users. With this effort, local, disparate networks will be connected to a single, integrated network. In the past, national security constraints required reliance on "sneaker net" including manually removing hard drives to share information. Raytheon's technology will enable DARPA's staff to send secure e-mail and file attachments, to share instant messages and to collaborate via voice and video in an environment that recognizes security clearances and manages access to information accordingly.

## Lockheed Martin JASSM Completes First Development Flight Test

Lockheed Martin's extended-range JASSM™ system has successfully performed its first development flight test at White Sands Missile Range, NM. The JASSM air-to-air standoff missile system is the world's first stealthy conventional cruise missile. Launched from an Air Force B-1B Lancer, flying at Mach 0.80 and 20,000 feet above the desert, the extended range JASSM (JASSM-ER) inert cruise missile successfully separated from the B-1B, deployed its wings and tail and started its engine. After weapon release, the missile climbed to the designated cruise altitude, navigated via predetermined waypoints and descended to a selected altitude above ground level for target ingress. The missile performed a terminal maneuver that enabled the missile to demonstrate the desired impact angle accuracy. "This test is an outstanding milestone for the JASSM-ER development and test team," said US Air Force Lt. Col. Stephen Davis, 677th Armament System Squadron commander at Eglin Air Force Base, FL. "This missile provides JASSM's proven lethality and accuracy with extended range to give the B-1B warfighter an outstanding operational capability for first-day strike of heavily defended targets." Current JASSM-ER is in Phase II development, which includes design and verification testing and culminates with flight testing. This flight test is the first all-up-round flight test to verify modifications specific to the extended range missile configuration. This flight will be followed by a series of integrated Air Force and Lockheed Martin development and evaluation test flights to prove out the JASSM-ER missile configuration on the B-1B platform. Each flight will be an end-to-end test, with successive tests providing an increasing evaluation of the total JASSM-ER system. "Key to the extended-range version of this missile is its leverage of JASSM's proven success, its incorporation of JASSM's aggressive reliability growth and quality program, and its focus on affordability with the introduction of a low risk and proven Williams International engine," said Mike Inderhees, JASSM program director at Lockheed Martin Missiles



and Fire Control. "JASSM-ER will have a range greater than 500 nautical miles. This development provided the Air Force and the warfighter with a JASSM-ER upgrade at the lowest risk and cost." A 2000 lb class weapon with a dual-mode penetrator and blast fragmentation warhead, JASSM-ER cruises autonomously in adverse weather, day or night, using a state-of-the-art infrared seeker in addition to the enhanced digital anti-jam Global Positioning System (GPS) receiver to find a specific aim point on the target. Its stealthy airframe makes it extremely difficult for air defense systems to engage.

## Harris Corp. Expands Radio Manufacturing Capacity

Harris Corp. is expanding manufacturing capacity and increasing employment at its RF Communications Division in Rochester, NY, to meet the growing demand for the company's advanced military communications solutions. Harris is significantly increasing the manufacturing capacity of the Rochester facility, where the company employees and government officials gathered recently to mark the expansion. "This investment in state-of-the-art technology supports our division's growing product and customer base and demonstrates our commitment and proven ability to serve the US Department of Defense and international customers," said Al Simon, vice president of operations, Harris RF Communications Division. "We take a commercial approach to manufacturing by building radios in anticipation of customer requirements. This ensures on-time deliveries, even on very short deadlines. In addition to the increased space and expanded product lines, our continuous attention to process improvement further streamlines production and reduces the time to market for new products." Harris is a major tactical communications supplier to all branches of the US Armed Forces and allied nations, worldwide. During the first three quarters of fiscal year 2006, revenue in the RF Communications Division was up 52 percent, compared to the prior-year period, as a result of demand for its Falcon® family of tactical radios. Harris will add approximately 200 new jobs between now and the end of calendar year 2006, bringing the company's total employment in Rochester to approximately 2200 people. "We have made a strong commitment to the Rochester community," said Chet Massari, president, RF Communications Division. "We announced plans in July 2005 to add 150 jobs and we are proud to have added over 200. Harris has grown employment substantially in the last two years and we will continue to draw on seasoned, local talent." ■

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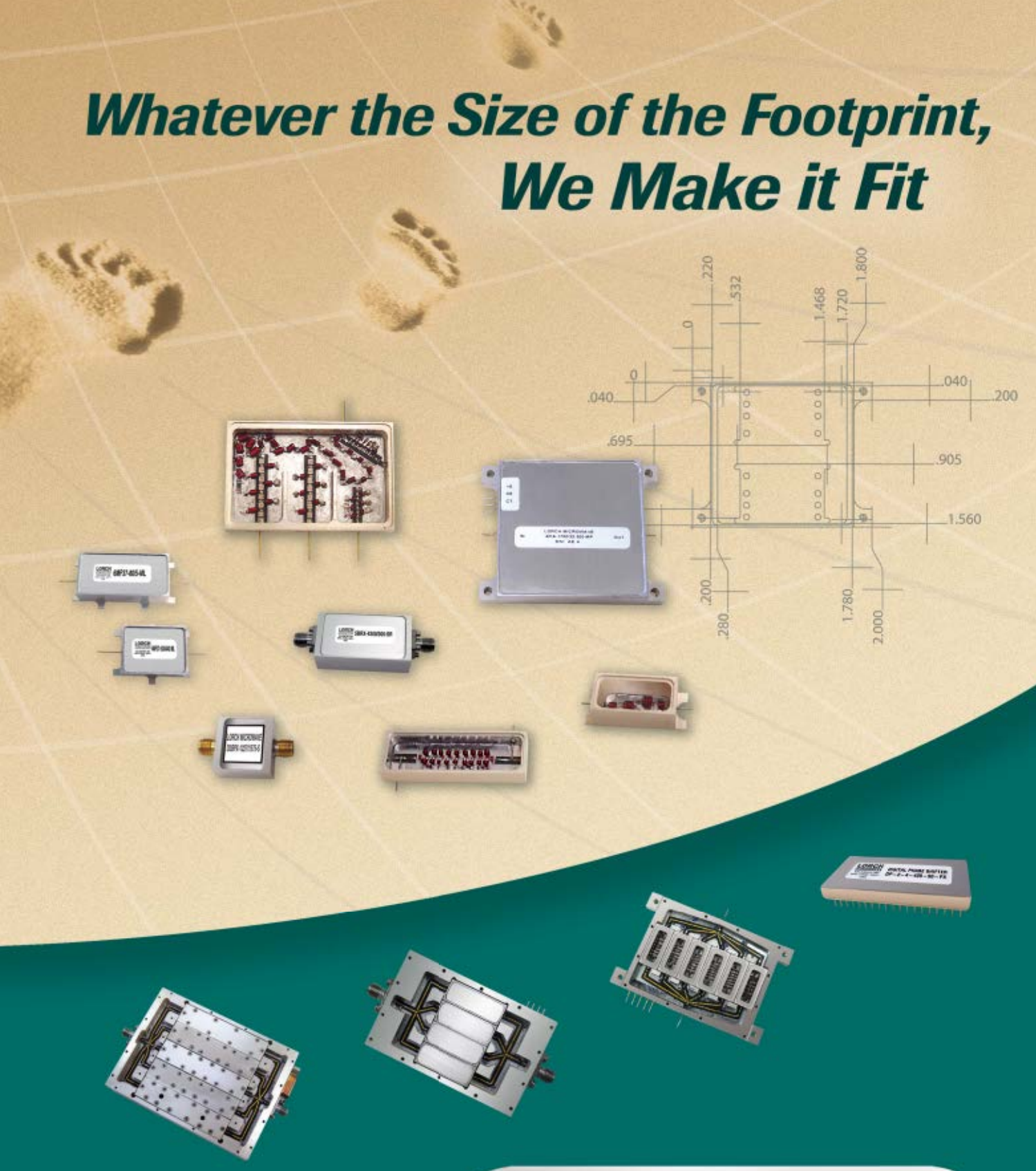


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## GAMBICA Joins Sensors KTN

The trade association for instrumentation, control, automation and laboratory technology in the UK — GAMBICA — has become an active supporter of the Sensors Knowledge Transfer Network (KTN), through its involvement with the KTN's Advanced Instrumentation Special Interest Group (AISIG).

The Sensors KTN, which is managed on behalf of the UK Department of Trade and Industry (DTI) by the National Physical Laboratory and Qi3, is the national sensing network, uniting the talent and expertise of the whole of the UK's sensing community, from academics and large industries, to small businesses, research councils and government departments. It embraces all sensing activity, from fundamental measurement principles to instrumentation, data processing, devices and innovative applications.

The AISIG will establish a UK community in the instrumentation sector and encourage industry and academics to develop innovative technologies, interact throughout the supply chain and compete on the world stage.

## High Speed Delivery for QinetiQ

LastMile Communications Ltd. has awarded QinetiQ a £6.2 M contract to develop a wireless transceiver system that will enable the high speed delivery of local information through a network of wireless nodes placed in existing roadside furniture, including road signs, gantries and lamp posts. The contract represents part of an extended strategic development agreement between the two companies and follows the successful completion of an earlier £1.6 M deal where QinetiQ de-risked the technology that will underpin the new system.

The new contract will result in the full development of a 65 GHz communications subsystem that will initially enable point-to-point high speed communications from wireless node to wireless node, removing the requirement for costly underground fibre optic cabling. The intention is then to develop further wireless node systems that enable roadside-to-vehicle, vehicle-to-roadside and vehicle-to-vehicle networking. LastMile's system allows information to be stored on individual wireless nodes, rather than at the centre of a network, thereby simplifying the process of information access.

Once commissioned, these systems are expected to enable retailers and other commercial services to communicate special offers and useful information instantly and very cheaply to all motorists within a given radius of a specific site. Users will be able to access this localised information via a range of mobile devices.

QinetiQ will initially deliver in the region of one hundred pre-production prototypes that will allow LastMile to conduct a pilot trial of the system. Under the terms of the agreement, QinetiQ is then responsible for supplying an initial production run of some tens of thousand units, during which time the technology will be matured and costs reduced.

## EADS and ND SatCom Join Forces in Germany

ND SatCom, together with its partner EADS Space Services, has won a major contract for the next step of the German Armed Forces' satellite communications programme, SATCOMBw Stufe 2. The project comprises the delivery of two military communication satellites, several fixed and transportable ground stations of various sizes as well as a bundle of communication services.

The contract period stretches over ten years, with an option for subsequent follow-up contracts. Based on the contract, ND SatCom will provide a complete ground segment containing the various user ground stations, the telemetry, tracking and command (TT&C) network as well as network management for monitoring and controlling the overall system. EADS is to deliver the space segment, which mainly includes two military satellites.

In order to serve the German Armed Forces in the most efficient way, ND SatCom and EADS set up a common special purposes company named MilSat Services, with EADS holding 74.9 percent and ND SatCom 25.1 percent. The joint venture will be in charge of the deployment and integration of the overall system for the customer. During the following operational phase, MilSat Services will provide additional military communication services and operate the two military satellites on behalf of the German Armed Forces.

## Saab to Acquire Ericsson Defence Business

Ericsson has agreed to sell its defence business, Ericsson Microwave Systems (EMW), and its 40 percent holding in Saab Ericsson Space to Saab, subject to approvals from relevant competition and defence authorities. Under the agreement Ericsson will retain the National Security and Public Safety business and parts of the Power Systems business, with the retained units employing around 300 individuals.

The purchase price is SEK 3.8 B in cash, with the transaction expected to be completed in September 2006. The sell-off also involves the transfer of approximately 1250 employees.

The agreement includes Ericsson's 20 percent ownership in the IG JAS consortia, Ericsson's shares in the joint ventures Thales EAW Systems and Ericsson Saab Surveillance Systems AB. The Ericsson defence business that Saab is acquiring had sales of approximately SEK 2 B in 2005 with good profitability.

Ericsson Microwave Systems is a leading provider of radar, command and control systems for defence applications. The company's comprehensive product portfolio includes the weapon locating system Arthur, the air surveillance system Giraffe and the operational airborne surveillance system Erieye.

Carl-Henric Svanberg, president and CEO, Ericsson, commented: "We are very pleased with this agreement since it gives EMW and its employees good possibilities to expand growth through Saab's strong market presence. Also, the EMW employees will now belong to a company with this area as a core business."

## e2v Meets X-ray Specs

e2v technologies has been selected to participate in the industrialisation phase for a key part of the X-ray Free Electron Laser (XFEL) research project based at DESY (the German Electron Synchrotron) in Hamburg, Germany. DESY's partner, the LAL Orsay Laboratory of CNRS (the National Centre for Scientific Research), is responsible for the development of the RF coupler technology for this programme and selected e2v to take part in the XFEL industrialisation phase on the merits of its materials technology, RF experience and manufacturing capabilities.

The European XFEL research project aims to create a unique source of very short pulses of highly intense X-rays that will be used to examine how materials and bio-molecules behave at the atomic level.

Under the agreement e2v will develop further the manufacturing technologies needed for mass production of the RF power couplers, which are key components to transfer high power RF into the superconducting cavities of XFEL's linear accelerator. A total of 1000 couplers will be required for the project, which is expected to be officially launched by the end of 2006.

Reflecting on the achievement, Jean-Louis Chinzi, president of e2v technologies SAS in France, said, "e2v is delighted to be a part of this major European project. Several superconducting accelerators, including the International Linear Collider, are expected to be built over the coming years, which will present further opportunities for those businesses with the technical capability and the capacity to work closely and effectively with the scientific community." ■

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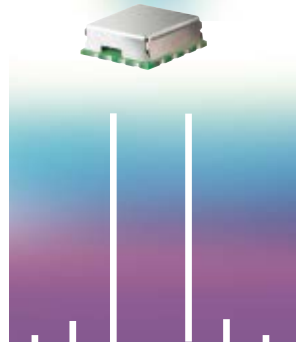

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|---|---|---|---|---|---|---|---|---|---|---|
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| LAVI-10VH+ | 300-1000 | 525-1175 | 60-875 | +21 | +33 | +20 | 6.3 | 50 | 45 | 22.95 |
| LAVI-17VH+ | 470-1730 | 600-1800 | 70-1000 | +21 | +32 | +20 | 6.8 | 52 | 50 | 22.95 |
| LAVI-22VH+ | 425-2200 | 525-2400 | 100-700 | +21 | +31 | +20 | 7.7 | 50 | 45 | 24.95 |
| LAVI-2VH+ | 2-1100 | 2-1100 | 2-1000 | +23 | +34 | +23 | 7.5 | 48 | 47 | 24.95 |
| LAVI-25VH+ | 400-2500 | 650-2800 | 70-1500 | +23 | +32 | +20 | 7.5 | 50 | 45 | 24.95 |

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| SBTC-2-20+ | 200-2000 | 50Ω | 3.49 |
| SBTC-2-25+ | 1000-2500 | 50Ω | 3.49 |
| SBTC-2-10-75+ | 10-1000 | 75Ω | 3.49 |
| SBTC-2-15-75+ | 500-1500 | 75Ω | 3.49 |
| SBTC-2-10-5075+ | 50-1000 | 50/75Ω | 3.49 |
| SBTC-2-10-7550+ | 5-1000 | 50/75Ω | 3.49 |

***U.S. Patent No. 6,963,255***

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## GaN Early Commercial Opportunities Lie in High Power Electronics

Strategy Analytics' latest study, "Gallium Nitride Markets: Commercial Markets Drive Power Electronics," concludes that military and high power electronics (HPE) applications will be the catalysts for the development of a gallium nitride (GaN) device market through 2010. Commercial wireless infrastructure applications will also drive demand in the future and the study forecasts that the total market for GaN microelectronic devices will grow at a CAGR of 151 percent through 2010.

As a material, GaN possesses some unique material properties, which would make it possible to create new devices with high breakdown voltage, extremely high power density and high gain at microwave frequencies. GaN's high temperature tolerance, alongside excellent thermal conductivity properties, makes it an ideal material for high power applications as well as for high temperature, extreme environment applications.

"The military and high power electronics market both have future needs that will make use of the advantages offered by wide bandgap materials such as GaN; and this will help the developing GaN device market," observes Asif Anwar, director of the Strategy Analytics GaAs service. "On the other hand, the needs of the commercial telecommunications wireless market have yet to really place the incumbent technologies, Si LDMOS and GaAs pHEMT, under major competitive strain although GaN will start to penetrate these markets over the next few years regardless."

"Future GaN device production will continue to be centered around non-native substrates," notes Stephen Entwistle, vice president of the Strategic Technologies Practice at Strategy Analytics. "We expect SiC material to continue to be the primary substrate of choice, while silicon substrates will also gain traction."

## China Will Be Largest IC-consuming Country by 2010

China is becoming the world hub for both semiconductor manufacturing and consumption, reports In-Stat. China consumed about 20 percent of total global semiconductor products in 2004; by 2010, it will consume one-third, making it the world's largest semiconductor consumer, the high tech market research firm says.

"China's government policy to develop the semiconductor industry and the general trend of the world's manufacturing industry moving into China are driving China as a prime location for IC design and manufacturing," says Anty Zheng, In-Stat analyst. "China's domestic semiconductor demand will increase at a CAGR of 21 percent from 2005 to 2009."

*Recent research by In-Stat found the following:*

- Computers are still the largest semiconductor area, with a share of 39 percent of China's IC market.
- The supporting industry, especially for equipment, is a weak link in China's semiconductor industry — almost all manufacturing equipment is imported.
- In order to fulfill the quick development of the foundry industry, China's local vendors should work on improving their packaging technologies.

This research is part of In-Stat's China Semiconductor and Electronics Manufacturing Service. This service forecasts semiconductor consumption in crucial segments, including 3G mobile devices and infrastructure, IC cards and consumer electronics devices. Semiconductor consumption for all of Asia is also addressed by country and an additional step toward presenting the whole picture is taken with an assessment of electronics manufacturers in China.

## UWB Shipments to Reach Nearly 300 Million in 2011

Several formidable-looking barriers appear, at first glance, to pose serious obstacles to widespread commercial success for ultrawideband (UWB). But closer examination reveals that few of them will drastically inhibit the market which, a new ABI Research study forecasts, will see nearly 300 million UWB shipments in 2011.

According to principal analyst Stuart Carlaw, some observers have pointed to the lack of standardization as a major barrier to growth in the UWB market. "The collapse of the UWB standard process was widely seen as a major faux pas," he notes, "but those inside the industry viewed it as the shackles being removed."

Similarly, many people point to 802.11n as the "UWB killer." The reality is that they are complementary. UWB's relationship to 802.11n may be compared to USB's relationship to Ethernet. Although that is an oversimplification, says Carlaw, "It is clear that UWB and 802.11n will co-exist and will be powerful allies for each other."

None of this is to say that no factors threaten UWB's success. Issues around global spectrum and regulatory approval, along with the need to drive down costs, power consumption and silicon package sizes, are all legitimate concerns that need to be addressed. There is a need to find global regulatory approval and common frequency allocations. In ABI Research's analysis, this is the real key to the UWB question. All signs are that the band between 7 and 8.5 GHz will be common across all regions. The European Communications Commission (ECC) has recently announced support for the 6 to 8.5 GHz band, while Japan looks set to ratify the 7 to 10 GHz band.

The recent announcement of the Bluetooth SIG's support for the WiMedia Alliance will also assist the drive for global regulatory approval, since the SIG has had significant success in doing this for its 2.4 GHz solutions. It is

worth noting that global regulatory endorsement is not a precursor to success, and that Bluetooth gained a lot of ground before receiving general regulatory approval.

The new study, "Ultrawideband: WiMedia, DS-UWB or C-Wave?," provides comprehensive analysis of the opportunities for each of the UWB solutions and the protocol they support. It forms part of two ABI Research subscription services, Home Networking Research Service and Short Range Wireless Research Service, which include a variety of research reports, regular market updates, ABI insight and analyst inquiry time.

## Global 3G Subscribers Pass 100 Million Mark in June

Strategy Analytics' on-going research into 3G subscriber tracking shows that more than 100 million people around the globe are now using WCDMA and CDMA2000 1x EV-DO 3G technology on their mobile phones, according to "Global 3G Subscribers Hit 100 Million Mark in June," published recently. 3G-user momentum is ramping up with a strong operator push complementing a rich portfolio of handsets. The number of 3G subscribers is growing fast — faster than the growth of GSM subscribers in the early 1990s. Strategy Analytics predicted reaching 106 million 3G users by the end of the second quarter, with the total number of 3G users worldwide hitting the magic 100 million mark for this populist technology in early June 2006. Sara Harris, senior industry analyst and author of this insight, commented, "Reaching the 100 million subscriber mark is a significant milestone for 3G, proving that it is finally beginning to come into its own. Much of this success is due to the strong pushes by influential carriers like NTT DoCoMo, Hutchison 3G and SK Telecom, and more recently Vodaphone and Verizon Wireless, who have worked hard to drive 3G uptake among their subscribers." David Kerr, vice president of the Global Wireless Practice, added, "Western Europe has overtaken Japan as 3G leader over the first half of 2006. However, the US market is set to grow rapidly in 2007, when Cingular rolls-out its HSDPA coverage in an attempt to catch up to the first mover advantages enjoyed by Verizon Wireless and Sprint Nextel, companies which have benefited from Qualcomm leadership in EV-DO." ■



## INDUSTRY NEWS

■ **Rosenberger of North America LLC** and **Agilent Technologies Inc.** announced that they have signed an agreement for Rosenberger to purchase assets and to license technology used by Agilent at its Santa Rosa, CA, cable assembly shop. Upon completion of the sale, Agilent will obtain these products and services from Lancaster, PA-based Rosenberger. Financial details were not disclosed, but the sale of this business is not expected to be material to Agilent's financial results.

■ **Analog Devices Inc.** (ADI) announced that it has entered into a definitive agreement to acquire privately-held **Integrant Technologies Inc.**, Seoul, Korea, an innovator in the field of high performance analog circuits designed for reconfigurable RF signal processing. The acquisition is expected to increase ADI's revenue by approximately one percent of sales in each of the next few quarters. Under the terms of the definitive stock purchase agreement, ADI expects to pay approximately $127 M in cash at the closing in exchange for substantially all of the outstanding shares of Integrant.

■ **ADC** and **Andrew Corp.** announced that they have entered into a definitive merger agreement to create a global leader in wireline and wireless network infrastructure solutions. The transaction, which was approved by the boards of directors of both companies, will build upon the complementary strengths of each company to create significant growth opportunities and global economies of scale to expand earnings. For the most recent reported 12 months as of May 31, 2006, combined sales for the two companies on a pro forma basis totaled approximately $3.3 B.

■ **Laird Technologies** announced that they have signed an agreement with **RFMD**® to jointly develop RF systems for the wireless industry. Laird and RFMD engineers will work together on developing integrated modules with built-in antennas to meet the cellular industry's need for more capabilities in smaller handset sizes. Products that result from the collaboration are expected to be available for sampling in 12 to 18 months.

■ **United Monolithic Semiconductor** and **Ansoft Corp.** announced the implementation of a GaAs IC design methodology for millimeter-wave frequencies utilizing on-chip electromagnetic extraction and a new Ansoft Designer®/Nexxim® RF design kit for the PH15 PHEMT process.

■ **Modelithics™** and **American Technical Ceramics Corp.** (ATC) announced a collaboration to develop substrate-scalable models for a wide variety of ATC's RF/microwave and Hi-Power passive components. The initial models will be made available starting in Q3 2006. These new Global Models™ represent entire families of ATC components on a continuous range of common substrate types and thicknesses.

■ **Applied Wave Research Inc.** (AWR®) announced that AWR and **Computer Simulation Technology** (CST) are cooperating to integrate CST MICROWAVE STUDIO® 2006, a three-dimensional electromagnetic technology, with AWR's Microwave Office® circuit design software suite. The cooperation is part of AWR's ongoing open systems strategy and leadership position in providing best-in-class EM tools for RF and microwave design.

■ **Fairchild Semiconductor** has expanded its Global Power Resource™ design centers to nine worldwide with the addition of a facility in São Paulo, Brazil. This new design center responds to the burgeoning high technology markets in South America. Fairchild is focusing on the South American region, projected by WSTS to have a 14 percent growth rate in 2006 and nearly 10 percent in 2007, to support its manufacturing customers.

■ **Locus Microwave Inc.** announced that effective immediately the company has moved to a new location in suburban State College, PA. The new location increases the facility size by three times and is specifically designed for the design and manufacture of RF and microwave products. The new address is: Locus Microwave Inc., 176 Technology Drive, Suite 200, Boalsburg, PA 16827 (814) 466-6275 or fax: (814) 861-5195.

■ **TriQuint Semiconductor Inc.** announced the intent to open a new design and support center in High Point, NC. The facility will be known as the North Carolina Design Center, and is part of TriQuint's ongoing program to work more closely with strategic partners and customers in the development of next-generation wireless modules and components.

■ **EM Research Inc.** has relocated into an upgraded, modern facility to accommodate significantly increased engineering and manufacturing demands. The new facility incorporates over 15,000 square feet of design, manufacturing and administration capacity. The company's mailing address is: PO Box 10430, Reno, NV 89510-0430.

■ **M2 Global Technology Ltd.** announced the company has expanded its San Antonio, TX headquarters. The new 25,000-square foot facility is located at 5714 Epsilon Drive, San Antonio, TX 78249.

■ **Spacek Labs Inc.** acknowledges the performance of its W-band front-end components on NASA's CloudSat Cloud Profiling Radar satellite. The company provided the LO source active X6 multiplier and both the up and downconverting mixers for the first satellite-based, millimeter-wave cloud radar. The satellite was successfully launched on April 28th, 2006. The Cloud Radar was activated for the first time on May 20th returning stunning cross-section images of a frontal system in the North Atlantic.

■ **Radio Waves Inc.** announced that all of the company's telecom antenna products are now compliant with the RoHS standard.

# Secret Unveiled.

TOP SECRET:

Code Name: "GALAXY"

Objective: Utilize space-age technology to combine rugged construction and low cost.

The Product: SGM "GALAXY" Series

## SGM "GALAXY" Series

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- Low Conversion Loss
- *SYNSTRIP*® Multi-Layer Technology
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| Model # | Frequency (MHz) | | Isolation (dB) [ Typ/Min ] | | | Conversion Loss (dB) [ Typ/Max ] | LO Power (dBm) [ Nom ] | Input IP3 (dBm) [ Typ ] |
|---|---|---|---|---|---|---|---|---|
| | LO/RF | IF | LO/RF | LO/IF | RF/IF | | | |
| **SGM Series** | | | | | | | | |
| SGM-2-7 | 250 - 3250 | DC - 700 | 30/15 | 10/5 | 30/15 | 6.5/8.5 | 7 | +10 |
| SGM-2-13 | 250 - 3250 | DC - 700 | 30/15 | 10/5 | 30/15 | 6.5/8.5 | 13 | +16 |
| SGM-2-17 | 250 - 3250 | DC - 700 | 30/15 | 10/5 | 30/15 | 6.5/8.5 | 17 | +20 |
| SGM-3-7 | 1350 - 7000 | DC - 2000 | 25/10 | 20/8 | 20/10 | 7/9.5 | 7 | +8 |
| SGM-3-13 | 1350 - 7000 | DC - 2000 | 25/10 | 20/8 | 20/10 | 7/9.5 | 13 | +14 |
| SGM-3-17 | 1350 - 7000 | DC - 2000 | 25/10 | 20/8 | 20/10 | 7/9.5 | 17 | +18 |

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■ **Merrimac Industries Inc.** announced it has been granted a patent for its Multi-Mix® Microtechnology from the United States Patent and Trademark Office entitled "Coupler Resource Module."

## CONTRACTS

■ **Anaren Inc.** has received a $6 M award from **Lockheed Martin** for electronic subassemblies that will help US Navy helicopters detect and identify enemy radar. Designed to process radar signals detected by a receiver, Anaren's Passive Ranging Subsystem is a major component of the AN/ALQ-210 Electronic Support Measures system, a sophisticated device carried aboard military helicopters and fixed wing aircraft to warn of possible threats. Anaren will deliver 31 passive ranging subsystems to Lockheed Martin starting in April 2007.

■ **TRAK Microwave Corp.** announced that it has been selected by a South Korean Prime Contractor to supply a sophisticated RF/microwave subsystem valued in excess of $4.5 M for use by a critical Korean Navy program. Over the three-year period of performance of the contract, TRAK will deliver 122 subsystems, inclusive of engineering services.

## FINANCIAL NEWS

■ **Sirenza Microdevices Inc.** reports sales of $20.9 M for the first quarter ended March 31, 2006, compared to $12.2 M for the same period in 2005. Net income for the quarter was $1.6 M ($0.04/per diluted share), compared to a net loss of $1.8 M ($0.05/per basic and diluted share) for the first quarter of last year.

■ **RF Industries Ltd.** reports sales of $3.8 M for the second quarter ended April 30, 2006, compared to $3.6 M for the same period in 2005. Net income for the quarter was $395,000 ($0.11/per diluted share), compared to $163,000 ($0.04/per diluted share) for the second quarter of last year.

## NEW MARKET ENTRY

■ **Precision Connector Inc.**, Franklin, IN, is a new coaxial connector manufacturer specializing in precision connectors. The company will offer adapters, cable connectors and receptacles in the following connector series: 1.85, 2.4, 2.92 and 3.5 mm. Also offered are SMA, TNC and N series to flexible low loss cable. For more information, contact Steve McGeary at (317) 346-0029.

## PERSONNEL

■ Donald "Shep" Shepherd, founder and president of AR Worldwide RF/Microwave Instrumentation, announced the appointment of **Jim Maginn** to chief executive officer. Maginn has assumed the CEO position, leaving AR Worldwide founder and president Shepherd more time to focus on the company's future growth plans. A fourteen-year veteran of AR Worldwide, Maginn, who previously held the post of chief operating officer, rose

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through the ranks from VP, engineering and manufacturing to become the first CEO to succeed Shepherd.


▲ Steven J. Schaefer

■ Cobham Defense Electronic Systems announced the appointment of **Steven J. Schaefer** to the position of president, Sensor and Antenna Systems. In this capacity, Schaefer is responsible for Atlantic Microwave, Atlantic Positioning Systems and Nurad Technologies Inc. Previously, Schaefer was senior vice president at Paratek Microwave and president of Kaydon Power and Data Group.

■ Z-Communications Inc. announced the appointment of **Mahadevan Sridharan** (Sri) as the company's president. Sri was previously vice president of engineering and marketing of Z-Communications. He holds a PhD degree in microwave circuit design and brings with him a wealth of experience spanning over 25 years in microwave component and system design and management. His diverse experience in design management and marketing combined with his vision for Z-Communications will provide a key role in the growth of the company.


▲ Larry Herring

■ SGMC Microwave announced the promotion of **Larry Herring** to the position of president. Herring has held the position of director of engineering since joining the company in 2001. His experience in the design and production of the firm's precision RF, microwave and millimeter-wave products, make him ideally suited to lead the company.

■ CAP Wireless Inc. announced the appointment of **R.E. "Skip" Hoover** as vice president, sales. Hoover has held similar positions at M/A-COM, WJ and Sirenza Microdevices. He has extensive experience working in the RF analog devices and subsystems business in both commercial and military/aerospace markets. Hoover is a veteran of the US Air Force and holds a BS from Long Beach State University.


▲ Donald Barnas

■ Aethercomm Inc. announced the addition of **Donald Barnas** to the company's team as director of business development. In his role, Barnas will have global responsibilities of generating new business opportunities. Prior to joining Aethercomm Inc., Barnas was the director of design and manufacturing centers for Richardson Electronics Ltd. Barnas has held senior positions in engineering, sales and business development for M/A-COM and General Dynamics Corp.

# RF Switches

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### High Isolation


**60 ~ 70 dB Isolation, DC to 4 GHz**

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- +52 dBm Input IP3
- MSOP8 or QFN Package

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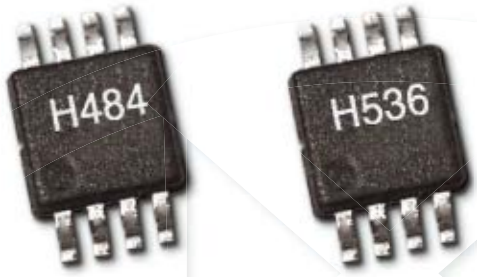


**+41 dBm P1dB +72 dBm IIP3**

**+37 dBm P1dB +56 dBm IIP3**

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- Excellent Isolation, 27 to 30 dB
- Ultra Small MSOP8

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| | Frequency (GHz) | Function | Insertion Loss (dB) | Isolation (dB) | Input P1dB (dBm) | Part Number |
|---|---|---|---|---|---|---|
| NEW! | DC - 6 | SPST, Failsafe | 0.7 | 25 | 27 | HMC550 (E) |
| | DC - 2.5 | SPDT, CATV | 0.6 | 58 | 28 | HMC348LP3 (E) |
| | DC - 3.5 | SPDT, Hi Isolation | 0.5 | 45 | 25 | HMC284MS8G (E) |
| | DC - 4 | SPDT, Hi Isolation | 0.9 | 65 | 31 | HMC349LP4C |
| | DC - 4 | SPDT, Hi Isolation | 0.9 | 57 | 31 | HMC349MS8G (E) |
| | DC - 12 | SPDT, Hi Isolation | 1.5 | 55 | 27 | HMC232LP4 (E) |
| | 0.2 - 2.2 | SPDT, 10W, Failsafe | 0.4 | 40 | > 40 | HMC546MS8G (E) |
| NEW! | 0.2 - 2.7 | SPDT, 10W, Failsafe | 0.4 | 35 | 40 | HMC546LP2 (E) |
| | 0.824 - 0.894 | SPDT, 10W, T/R | 0.6 | 22 | > 40 | HMC446 (SOT26) (E) |
| | DC - 3 | SPDT, 3W, T/R | 0.3 | 30 | 37 | HMC595 (E) |
| | DC - 3 | SPDT, 5W, T/R | 0.3 | 30 | 39 | HMC574MS8 (E) |
| | DC - 3 | SPDT, 10W, T/R | 0.5 | 30 | > 40 | HMC484MS8G (E) |
| NEW! | DC - 4 | SPDT T/R | 0.25 | 23 | 39 | HMC544 (E) |
| | DC - 6 | SPDT T/R | 0.5 | 27 | 37 | HMC536MS8G (E) |
| | 5 - 6 | SPDT T/R | 1.2 | 31 | 33 | HMC224MS8 (E) |

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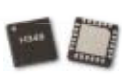

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■ LNX announced that **Frank Magnante** has joined LNX Corp. as chief scientist. Magnante will be responsible for the design and development of advanced microwave subsystems integrating microwave and digital technology for the EW and ECM markets. He brings over 40 years of experience in the design of advanced microwave subsystems. Before joining LNX, he served as vice president of engineering for a major defense contractor and led the design, development and implementation of EW and ECM systems used on platforms such as the F-15, F-16, Rapport and Nimrod.

■ To celebrate the achievements of **Bill Trowbridge**, founder and former chairman of Vector Fields Ltd., who retired last year, the company announced that it will issue an award for the best 2006 student paper. The award will be given for the best academic publication on work that uses either of Vector Fields' electromagnetic design software, Concerto or Opera, which is published in the open literature between January 1, 2006 and December 31, 2006. For more information, visit www.vectorfields.com.

## REP APPOINTMENTS

■ **Mica Microwave** announced the appointment of **Jay Stone Associates** as its exclusive sales representative for its line of isolators, mixers, gain equalizers and detectors for northern California and northern Nevada. Jay Stone Associates can be contacted at 2109 O'Toole Avenue, Suite M, San Jose, CA 95131 (408) 428-2500, fax: (408) 428-9000 or e-mail: sales@jsarep.com. In related news, Mica announced the appointment of **Odyssey 1** as its exclusive sales representative in Utah, Colorado, Wyoming, Montana and Idaho. Odyssey 1's main office is located at 970 East 3300 South, Suite 7A, Salt Lake City, UT 84106 (801) 485-4728, fax: (801) 485-4753 or e-mail: donr@odyssey1.com.

## WEB SITES

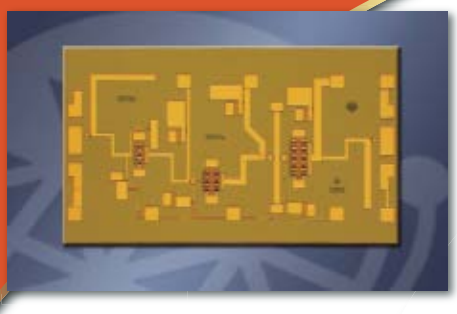
■ **Mimix Broadband Inc.** announced that it has launched its enhanced and redesigned web site (www.mimixbroadband.com) featuring a searchable product database that allows users to sort by category or application, as well as search for specific parts and product types. The site's new design reflects the company's expanded product offerings, worldwide sales coverage, application tools to support customers and technology development.

■ **Micro-Mode**'s new e-commerce site, www.smpconnectors.com, allows engineers to get high quality, high performance blindmate and threaded connectors quickly. The site features 360° product views along with data sheets and real time inventory. Account details are only a few clicks away and allow customers to easily check order status and download invoices safely and securely. The company stocks thousands of SMP, SMPM and MSSS connectors along with cable assemblies and tooling.

# MICROWAVE PAs

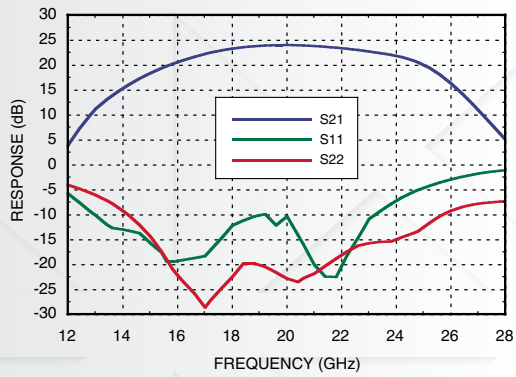
## UP TO +27 dBm POWER OVER 6 TO 32 GHz!

### HMC498 MEDIUM POWER AMPLIFIER, 17 - 24 GHz

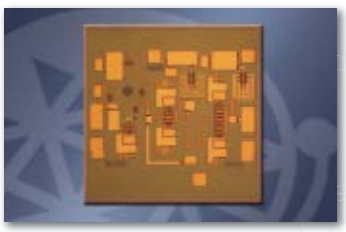


- Saturated Power: +27 dBm @ 25% PAE
- 24 dB Gain
- +34 dBm Output IP3
- +5V Supply Voltage

**BROADBAND GAIN & RETURN LOSS**

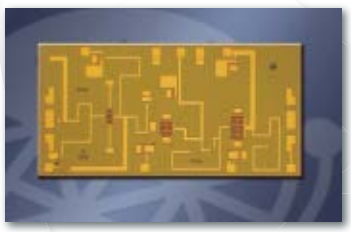



### HMC451, 5 - 20 GHz



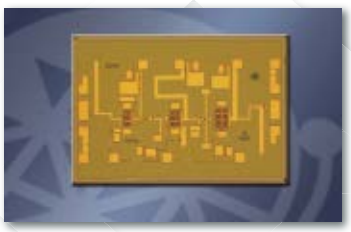
- +20 dBm P1dB
- 22 dB Gain
- +30 dBm Output IP3
- +5V Supply Voltage

### HMC490, 12 - 17 GHz

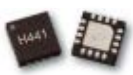


- 2 dB Noise Figure
- +26 dBm P1dB
- 27 dB Gain
- +35 dBm Output IP3
- +5V Supply Voltage

### HMC499, 21 - 32 GHz



- +24 dBm P1dB
- 16 dB Gain
- +33 dBm Output IP3
- +5V Supply Voltage

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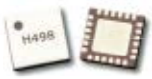


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# MICROWAVES IN EUROPE: MARKETS AND TECHNOLOGIES

*In 2006, how strong is the European microwaves industry? Is it responding to the challenges of globalisation? Is the European Union united in its efforts? And what are the future technological trends?*

The one certainty with technology is that it develops and changes at its own and often unpredictable pace. Crucial to determining the success and progression of any industry is how effectively it embraces new technology, exploits it and adapts it to the reality of the marketplace. The RF and microwave industry is no exception. With its focus firmly on Europe this article attempts to take a reading of the current status of academic and commercial development and identify and quantify the main trends influencing it.

The information/Internet age has technologically and commercially 'shrunk' the globe so that knowledge, expertise, investment and new markets are easily accessible. The result is a more open and competitive market, particularly in the mass production sector where low cost, large scale operations in China, other Asian markets and emerging economies such as India are having an impact. As a consequence, Western Europe in particular has had to adapt, realign and focus on its strengths. It is now capitalising on its wealth of expertise and technical skills to become a hub and resource for research and development and value added products.

In Eastern Europe the opening up of borders and the removal of trade barriers has led to expansion and a developing market that promises scope for cross-European trade. The region is also a potential source of competition due to the growth in low cost manufacturing facilities. But will the rest of Europe treat this as a threat or be proactive and take the opportunity to invest and forge partnerships?

Whether the influential factors affecting the European RF and microwave industry are global or regional it is how they are being addressed that is critical. Over recent years great strides have been made towards creating an environment in Europe that offers an inclusive, collaborative approach to technological and market development. Structured, coherent policies have been devised and implemented, backed up by financial and practical support. Examples include the European Union Networks of Excellence (NoE) Programmes, many of which target the RF and microwave sector, and significant pan-European initiatives such as the Galileo Project, which are providing focus and momentum.

These initiatives will feature at this year's European Microwave Week (EuMW) in Manchester and be the subject of papers in the four individual conferences: the European Microwave Conference (EuMC), the European Conference on Wireless Technology (ECWT), the European Microwave Integrated Circuits Conference (EuMIC) — formerly the GAAS® Symposium — and the European Radar Conference (EuRAD). In advance, *Microwave Journal* has capitalised on its unique access to the conference chairmen, academic contributors and key industrial players to evaluate current activities in the European RF and microwave market and identify the trends shaping its future.

In this report, the individual conference chairmen each present an overview of their market sectors, complemented by a commercial perspective as executives of companies that play a key role in the European microwave industry contribute to the 'company survey'. To provide an international viewpoint, *Microwave Journal* has canvassed companies across the globe actively participating in the European microwave market.

RICHARD MUMFORD
Microwave Journal *European Editor*

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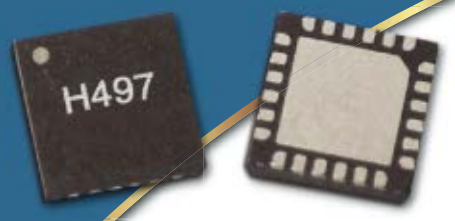


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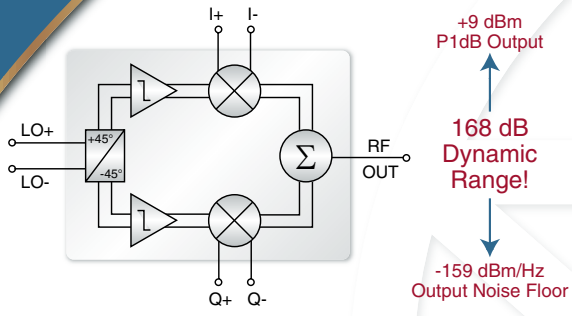


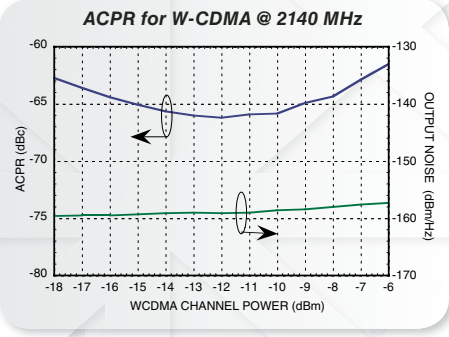


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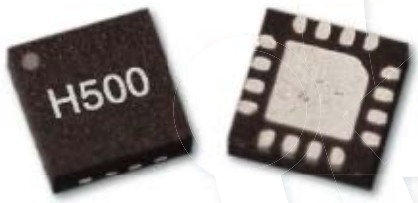


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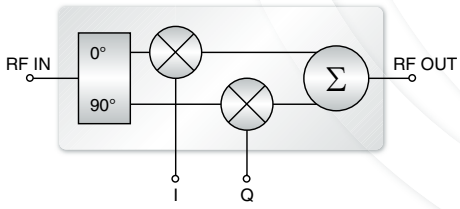


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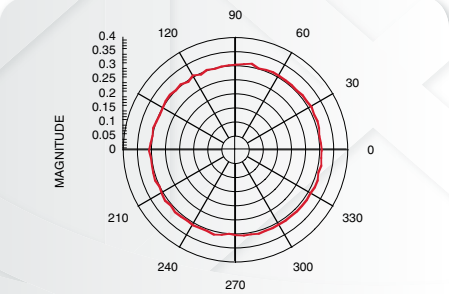


*HMC500LP3 Polar Plot*


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In order to provide a context for these opinions let's first consider the political, commercial and technological environment in which the European microwave industry is operating.

## EUROPEAN PERSPECTIVE

By its very nature Europe is a conglomeration of individual and disparate countries with its own established industries and centres of academic and commercial research. In the past, many of these research establishments would have worked independently to a large degree. However, that has gradually changed with the expanded European Union putting greater emphasis on co-operation and collaboration to pool resources, harness technological expertise and forge partnerships to create real and productive initiatives.

Technology and research is at the core of the EU's strategy to deliver growth, competitiveness and employment while maintaining social and environmental sustainability. The RF and microwave field encompasses many leading edge technologies that can stimulate such growth. In particular wireless applications are seen as fundamental to the European Union's future vision of 'ambient intelligence' featuring 'always-on' connectivity for the citizen, while the defence and space sectors are key too.

A major medium for addressing these issues is the EU Framework Programmes (FPs), which identify key areas of research and development and organise and fund specific pan-European collaborative projects. Through the Networks of Excellence Programmes the current 6th FP is supporting many large microwave-related activities.

These include projects for power amplifiers (TARGET), RF MEMS (AMICOM), antennas (ACE), integrated microsystems (INTEGRAM-plus) and 4G antennas (4MORE). More broadly other projects address wireless communications (NEWCOM) and wireless deployable networks (WIDENS). In the satellite field SatNEx aims to rectify the fragmentation in satellite communications research by bringing together Europe's leading academic institutions and research organisations.

The 6th FP is due to finish at the end of 2006 when it will be replaced by the new 7th Framework Programme, which will run for seven years (2007–2013) with a budget of approximately €54 B. Wireless technologies, both in terms of basic technologies and applications, will be key targets for FP7 projects, while a recent amendment to the FP7 proposal emphasised the importance of involving small and medium sized enterprises.

All these initiatives provide incentives and a focus for activity. The same can be said for the Galileo Project to create Europe's own global navigation satellite system, providing a highly accurate, guaranteed global positioning service under civilian control. When fully deployed the Galileo system will consist of 30 satellites and will be interoperable with GPS and GLONASS. As it progresses the project is gaining momentum and stimulating investment and technological advancement.

## RF AND MICROWAVE

The RF and microwave industry is diverse, providing components, systems and subsystems for applications

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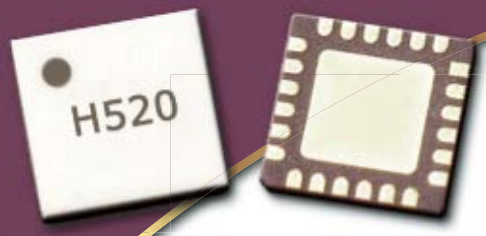


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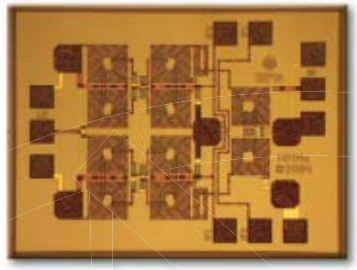

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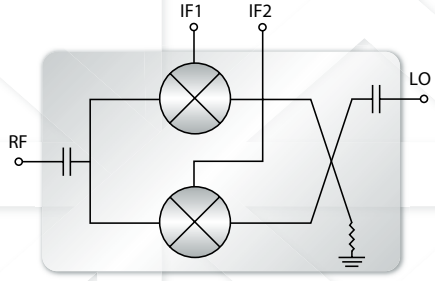
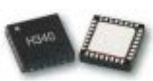



## A SELECTION OF OUR I/Q & IMAGE REJECT MIXERS

| | RF / LO Freq. (GHz) | Function | IF Freq. (GHz) | Conv. Gain (dB) | Image Rejection (dB) | Input IP3 (dBm) | Package | Part Number |
|---|---|---|---|---|---|---|---|---|
| | 1.7 - 4.5 | I/Q Mixer / IRM | DC - 1.5 | -8 | - | 23 | LP5 | **HMC340LP5** |
| | 4 - 8.5 | I/Q Mixer / IRM | DC - 3.5 | -7.5 | 40 | 23 | LC4 | **HMC525LC4** |
| | 5.9 - 12.0 | I/Q Mixer / IRM | DC - 1.5 | -8 | 30 | 18 | Chip | **HMC256** |
| | 6 - 10 | I/Q Mixer / IRM | DC - 3.5 | -7 | 40 | 23 | LC4 | **HMC520LC4** |
| | 6 - 10 | I/Q Mixer / IRM | DC - 3.5 | -7.5 | 40 | 28 | LC4 | **HMC526LC4** |
| | 8.5 - 13.5 | I/Q Mixer / IRM | DC - 3.5 | -7.5 | 38 | 24 | LC4 | **HMC521LC4** |
| | 8.5 - 13.5 | I/Q Mixer / IRM | DC - 2 | -7.5 | 34 | 28 | LC4 | **HMC527LC4** |
| | 11 - 16 | I/Q Mixer / IRM | DC - 3.5 | -7.5 | 35 | 24 | LC4 | **HMC522LC4** |
| | 11 - 16 | I/Q Mixer / IRM | DC - 3.5 | -8 | 35 | 27 | LC4 | **HMC528LC4** |
| | 15 - 23 | I/Q Mixer / IRM | DC - 3.5 | -8 | 25 | 25 | LC4 | **HMC523LC4** |
| | 22 - 32 | I/Q Mixer / IRM | DC - 3.5 | -10 | 23 | 20 | Chip | **HMC524** |
| *NEW!* | 31 - 38 | I/Q Mixer / IRM | DC - 3.5 | -10.5 | 17 | 21 | Chip | **HMC555** |
| *NEW!* | 36 - 41 | I/Q Mixer / IRM | DC - 3.5 | -11 | 18 | 23 | Chip | **HMC556** |
| | 26 - 33 RF | Sub-Harmonic I/Q Mixer / IRM | DC - 3 | -11 | 22 | 16 | Chip | **HMC404** |

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as varied as telecommunications, telematics, medical, defence, automotive, aerospace and satellite communications. All are the subject of R&D activity in Europe where telecommunications remains a key driver. Now that 3G is finally making it's presence felt the industry is squaring up to address the challenges of 3.5G and 4G with cognitive radio further down the developmental road.

Research into RF MEMS applications is to the fore. Europe is also focusing on microsystems and nanosystems. A new Framework 6 Integrated Project, INTEGRAMplus, was announced just prior to going to press. This €6.5 M European Commission funded, three-year programme will focus on integrating silicon-based MEMS components. Its ultimate goal is to stimulate take-up of micro and nanotechnologies by end users by providing flexible design and prototyping services, based on standardised modules, with a route to manufacture for highly integrated microsystems.

At the high frequency end of the spectrum there is increasing interest in exploiting mm-wave frequencies from 60 GHz upwards, helped by significant progress in the high frequency behaviour of deep sub-micron Silicon-on-insulator technologies. Also the development and adoption of 77 GHz automotive radar systems are impacting on the high end automotive sector, which is of key strategic importance to Europe's economy. As well as automotive applications millimetre-wave technologies have been developed for point to point communications while passive millimetre-wave imaging is being employed for security applications. New markets and opportunities are also opening up for terahertz technologies in Europe.

Other factors to note that are likely to influence the RF and microwave industry in the future include: technological innovations to support higher integration, multifunctional MMICs enabling the combination of low power (logic) and high power switching and power amplification on a single chip. There is also demand for technologies with the ability to 'shrink' the size of the die, thereby enabling smaller footprints and lower costs, along with the availability of higher performance, higher frequency, lower cost plastic packaging.



## WIRELESS TECHNOLOGIES

In an age when access to information, communication and infotainment, any time, any place, anywhere has become a pre-requisite for modern life it is not surprising that the wireless technologies market is a focus for development and innovation. The mobile phone market is a prime example of the public's hunger as the latest research from Informa Telecoms and Media's, World Cellular Information Service (WCIS) shows that in 30 countries the number of mobile phone subscriptions exceeds the size of the population and in the UK, Sweden and Italy penetration has passed 110 percent.

Also, the fact that in 2005 Russia was the third largest mobile market in the world through adding more than 50 million mobile subscriptions is evidence of the impact that the opening up of political and territorial borders is having on Eastern Europe where there has been significant mobile infrastructure expansion.

However, rising numbers does not mean rising revenues for operators as regulatory and competitive pressures are squeezing margins. This point is illustrated by the fact that in Western Europe average revenues per active subscriber fell slightly in 2005 and are forecast to do the same in 2006. Nordic operators are faring particularly badly, prompting them to invest in emerging wireless markets including Eastern Europe.

That is the market but what is the technology feeding it? It may be hard to believe but one bright star is 3G. Licenses are finally being used, the infrastructure is shipping and handsets enabled to utilise the technology are more widely available. As would be expected Asia is strong but the European market has picked up significantly too.

Away from mobile phone technology 2006 is seeing advances in high frequency electronics being applied to other distinct wireless communications applications and services. Also, the desire for multimedia access in the home and 'on the go' is a key factor in driving the development of WiFi, WiMAX, UWB, MIMO and 3G HSDPA/HSUPA. On the latter technology, research from Informa Telecoms & Media states that HSDPA networks are expected to be switched on in all major Western European markets before the end of 2006.

## SEMICONDUCTORS

The semiconductors market is one where developmental and price pres-

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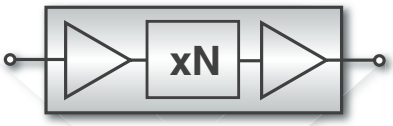


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## ACTIVE FREQUENCY MULTIPLIERS

| | Input Freq. (MHz) | Function | Output Freq. (GHz) | Input Power (dBm) | Output Power (dBm) | 100 kHz SSB Phase Noise (dBc/Hz) | Package | Part Number |
|---|---|---|---|---|---|---|---|---|
| NEW! | 3000 - 4500 | Active x2 | 6 - 9 | 0 | 17 | -140 | LP4 | **HMC575LP4 (E)** |
| | 4500 - 8000 | Active x2 | 9.0 - 16.0 | 2 | 15 | -140 | LP4 | **HMC368LP4 (E)** |
| | 4950 - 6350 | Active x2 | 9.9 - 12.7 | 0 | 4 | -142 | LP3 | **HMC369LP3 (E)** |
| NEW! | 9000 - 14500 | Active x2 | 18 - 29 | 3 | 17 | -132 | Chip | **HMC576** |
| NEW! | 9000 - 14500 | Active x2 | 18 - 29 | 3 | 15 | -132 | LC3B | **HMC576LC3B** |
| NEW! | 12000 - 16500 | Active x2 | 24 - 33 | 3 | 17 | -132 | Chip | **HMC578** |
| NEW! | 12000 - 16500 | Active x2 | 24 - 33 | 3 | 15 | -132 | LC3B | **HMC578LC3B** |
| NEW! | 13500 - 15500 | Active x2 | 27 - 31 | 5 | 20 | -128 | LC4B | **HMC577LC4B** |
| NEW! | 16000 - 23000 | Active x2 | 32 - 46 | 3 | 13 | -127 | Chip | **HMC579** |
| | 2450 - 2800 | Active x4 | 9.8 - 11.2 | -15 | 3 | -142 | LP4 | **HMC443LP4 (E)** |
| | 3600 - 4100 | Active x4 | 14.4 - 16.4 | -15 | 0 | -140 | LP4 | **HMC370LP4 (E)** |
| | 1237.5 - 1400 | Active x8 | 9.9 - 11.2 | -15 | 6 | -136 | LP4 | **HMC444LP4 (E)** |
| | 618.75 - 687.5 | Active x16 | 9.9 - 11 | -15 | 7 | -130 | LP4 | **HMC445LP4 (E)** |

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sures have brought about changes in structure, geographical activity and the areas of application. According to World Semiconductor Trade Statistics (WSTS) worldwide chip sales increased by 6.8 percent in 2005. However, the European semiconductor market did not follow suit, decreasing by 0.4 percent over the year with major contributory factors being the shift in mass market semiconductor manufacturing to the Far East and ongoing outsourcing activities.

In particular fabless manufacture has had an impact brought about by the fact that many companies researching and developing the next generation of semiconductors did not have the financial resources to be able to invest in fabricating their own chips. The result being the explosion in fabless companies with recent estimates being that globally there are over 750 fabless companies served by less than 15 independent foundries. The Fabless Semiconductor Association (FSA) reported that in 2005 fabless companies accrued revenue of over $40 B, accounting for nearly 18 percent of total semiconductor sales.

Similarly, many fabless companies themselves, along with wafer companies and integrated device manufacturers are contracting with outsourced semiconductor assembly and test companies. Key reasons being the search for smaller, higher density devices, along with materials with the capacity to offer better speed and performance.

These are all factors that have changed the dynamic of the semiconductor industry globally but particularly in Europe. However, Europe is not taking a back seat in this sector. The European Commissions' Network of Excellence Programmes are at the forefront in the battle to keep Europe competitive in an ever changing market and it is achieving its targets for grouping European business into pan-European partnerships. Technologically, the NoE activity related to the development of gallium nitride and particularly the advancement of GaN MMICs is encouraging.

In the RF and microwave field, the mobile handset sector, the largest single product market for semiconductors outside the PC market, is dominant but others are significant too. For instance, the automotive semiconductor market is creeping up to 10 percent of the total semiconductor market and is particularly strong in Europe. Growth in this sector is forecast to continue as technological advances are made with regards to telematics, infotainment, vehicle networking and inter-vehicle networking.

## DEFENCE

The War on Terrorism, home security and regional volatility have put national and international defence and security in the spotlight as constantly changing threats have to be addressed. As a result Europe must militate against threats that are more diverse, less visible, and less predictable. Political, social, demographic and economic factors are key influences on the development and direction of European defence and security, with the challenge being to adapt and prosper within this changing environment.

A starting point is the European security strategy — *A Secure Europe in a Better World* — which proposes three strategic objectives for the Euro-

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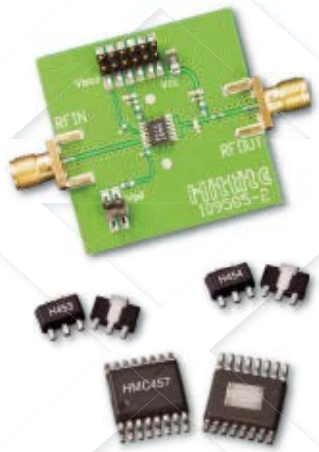


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pean Union: 'addressing threats, building security in our neighbourhood and an international order based on effective multilateralism'. As well as facing direct threats the strategy proposes that Europe must use its technological strengths to build the capability for deploying significant resources for peacekeeping, humanitarian aid and state-building activities, either on its own or in international alliances.

To achieve this requires an optimal use of the resources and the development of European industrial capabilities. To meet these challenges both governments and commercial enterprise are tending towards a collective European approach. Particular European Union initiatives include the development of a European Security Research Programme (ESRP), as part of the 7th EU Research Framework Programme, a key element of which is the Preparatory Action for Security Research (PASR).

In its first two years the European Commission started 25 demonstration projects and supporting actions. The set security priorities included protection of networked systems, protection against terrorism, enhancing crisis management, interoperability and integrated systems, and improving situation awareness. However, there are concerns with regards to its adequate funding after the European Parliament reduced the proposed budget for the third year of PASR from the €24 M proposed by the European Commission to €15 when voting on the EU 2006 Budget at the end of 2005.

Such programmes are not only paramount to security but also to the development of new technology by providing a structured and stable platform for initiatives to be taken.

Increasingly technologies, techniques and components developed for commercial applications are being adopted by the military sector. Significant recent trends include the convergence between radar and communications techniques and technologies, particularly CW-type radars taking advantage of low cost microwave components, and radars being developed that exploit communications techniques Also, research is being carried out into conformal antennas, the use of metamaterials and plasma antennas as well as the development of sparse antenna arrays.



## OVERVIEWS AND SURVEYS

The European Perspective provides the background and the context in which the European microwave industry is currently operating but how are the different technology sectors and individual companies faring is this environment? To obtain some answers the author has sought the views of the academic and industrial and taken European Microwave Week as its focus. The EuMW chairman offers a sector wide overview while the chairmen of the four individual conferences concentrate specifically on their market sectors. They consider how technology is developing and the long-term impact it is likely to have, while giving a perspective of how the sector fits into the overall microwave picture.

Industry gets to offer a commercial perspective and an insight into current market conditions and technological development via the Company Survey of executives from companies representing a wide cross section of the European microwave industry. The format is generally a brief overview of the company's microwave activity, followed by comments on technological and market initiatives.

To obtain a global picture, the International Perspective, first introduced in 2005, attempts to offer a flavour of how the European microwave industry and market is perceived worldwide. International players spanning the geographical and technological development spectrum proffer opinions on the practicalities, barriers and benefits of competing in the European microwave market.

## INDUSTRY-WIDE PERSPECTIVE

### *Microwave industry overview by EuMW General Chairman, Christopher Snowden*

If participation in European Microwave Week is a good barometer, then the RF and microwave industry looks particularly healthy as this year the number of technical papers submitted reached a record of over 1150. Significantly too, the 790 papers accepted for presentation across the four conferences come from 52 countries, confirming the globalisation trends in our industry. EuMW takes great care to reflect worldwide developments and has been tailored to cover a wide range of interests in the RF, microwave, millimetre and submillime-

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tre-wave fields including microwave and photonic devices, component technologies, circuits and systems, and this year a special effort has been made to focus on topical issues.

RF, microwave and millimetre-wave techniques are well covered by the European Microwave Conference, with both active and passive devices and circuits being prominent. The new European Microwave Integrated Circuits Conference addresses active devices and circuits based on compound semiconductors and other RF and microwave semiconductor materials. Record submissions for the European Conference on Wireless Technologies focus on circuit, sub-system and system level aspects of wireless communications, together with signal-processing techniques, while the European Radar Conference concentrates on radar techniques, systems, signal processing and applications. Common to all four conferences is an increased emphasis on applications.



Later in this article each of the conference chairmen proffer their views on the activity and developments in their particular field but first I shall try to highlight some general industry trends. Topical areas where there is significant activity include power amplifiers and linearization, ultra-wideband (UWB), terahertz technologies, metamaterials and MEMS. There is a very high degree of interest in antennas, sensing, phased arrays and propagation as well as filters, passive components and circuits.

Emerging technologies include techniques such as MIMO and imaging processes and the emphasis is very much on industrial and applications-oriented research. From a geographical perspective pan-European projects such as power devices (Si, GaAs, GaN) and power amplifiers have a significant role to play while defence and space initiatives, including satellite technologies are key areas of activity.

## RF AND MICROWAVE

### *Sector overview by EuMC, Chairman, Professor Tom Brazil*

The RF and microwave sector is currently developing extremely strongly across the world and Europe is no exception. Wireless applications are now seen as fundamental to the European Union's future vision of 'ambient intelligence' featuring 'always-on' connectivity for the citizen. Communications remains a key driver as GSM evolves through EDGE to advanced 4th generation systems, although there are great challenges in coping with the competing demands of linearity and efficiency in such emerging radio systems of very spectral efficiency. It is also clear that reconfigurability, so natural at the digital level, will be also required at the level of the microwave transceiver, leading ultimately to the 'cognitive radio' that can sense its environment and intelligently adapt itself to meet user needs optimally. RF MEMS can play a part here but more generally there are strong developments in Europe around microsystems and nanosystems, featuring distributed wireless sensors integrating many novel sensor technologies and addressing various applications ranging from RFID, climate monitoring, security and biomedical systems.

While wideband gap semiconductors open up undreamed of possibilities for microwave power generation per unit device width, there is also an

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| 150-75-3 | dc-18.0 | 0-75/5 | |
| 150-70 | dc-18.0 | 0-70/10 | |
| 150-70-1 | dc-18.0 | 0-70/10 | |
| 151-11 | dc-4.0 | 0-11/1 | |
| 152-90-3 | dc-26.5 | 0-90/10 | |
| 150T-11 | dc-18.0 | 0-11/1 | ◆ |
| 150T-15 | dc-18.0 | 0-15/1 | ◆ |
| 150T-31 | dc-18.0 | 0-31/1 | ◆ |
| 150T-62 | dc-18.0 | 0-62/2 | ◆ |
| 150T-70 | dc-18.0 | 0-70/10 | ◆ |
| 150T-75 | dc-18.0 | 0-75/5 | ◆ |
| 150T-110 | dc-18.0 | 0-110/10 | ◆ |
| 151T-110 | dc-4.0 | 0-110/10 | ◆ |
| 152T-55 | dc-26.5 | 0-55/5 | ◆ |

| Model | Frequency Range (GHz) | Attenuation Range (dB) | Notes |
|---|---|---|---|
| 3200-1 | dc-2.0 | 0-127/1 | |
| 3200-2 | dc-2.0 | 0-63.75/.25 | |
| 3200-1E-2 | dc-3.0 | 0-127/1 | |
| 3200-2E-2 | dc-3.0 | 0-63.75/.25 | |
| 3201-1 | dc-2.0 | 0-31/1 | |
| 3201-2 | dc-2.0 | 0-120/10 | |
| 3206-1 | dc-2.0 | 0-63/1 | |
| 3200T-1 | dc-2.0 | 0-127/1 | ◆ |
| 3206T-1 | dc-2.0 | 0-63/1 | ◆ |
| 3250T-63 | dc-1.0 | 0-63/1 | ◆ X |
| 4216-63 | 0.8-3.0 | 0-63/1 | |
| 4218-127 | 0.8-3.0 | 0-127/1 | |
| 4238-103 | .01-2.5 | 0-103/1 | |

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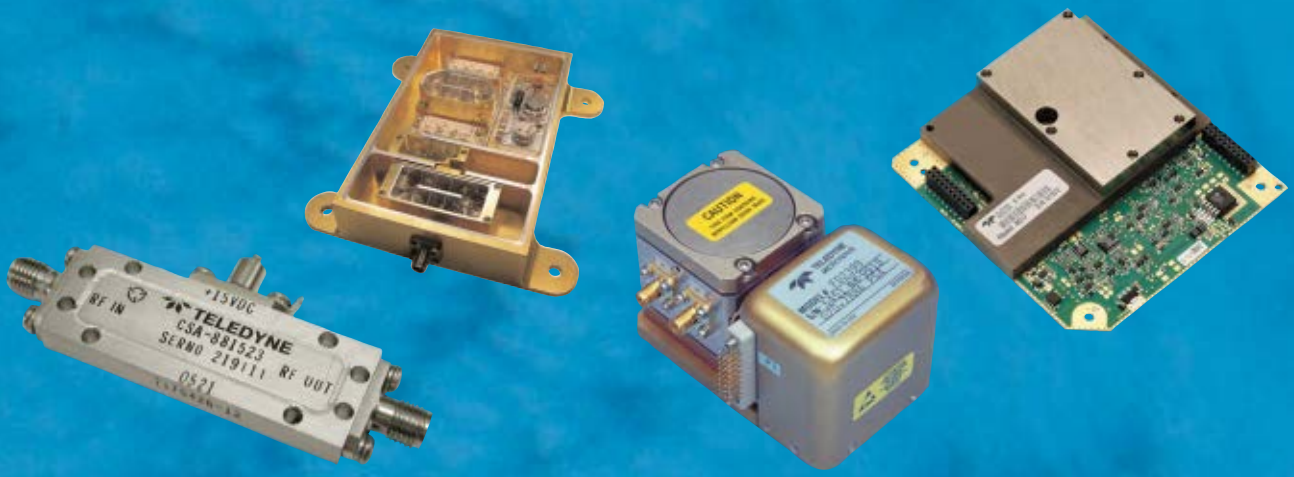


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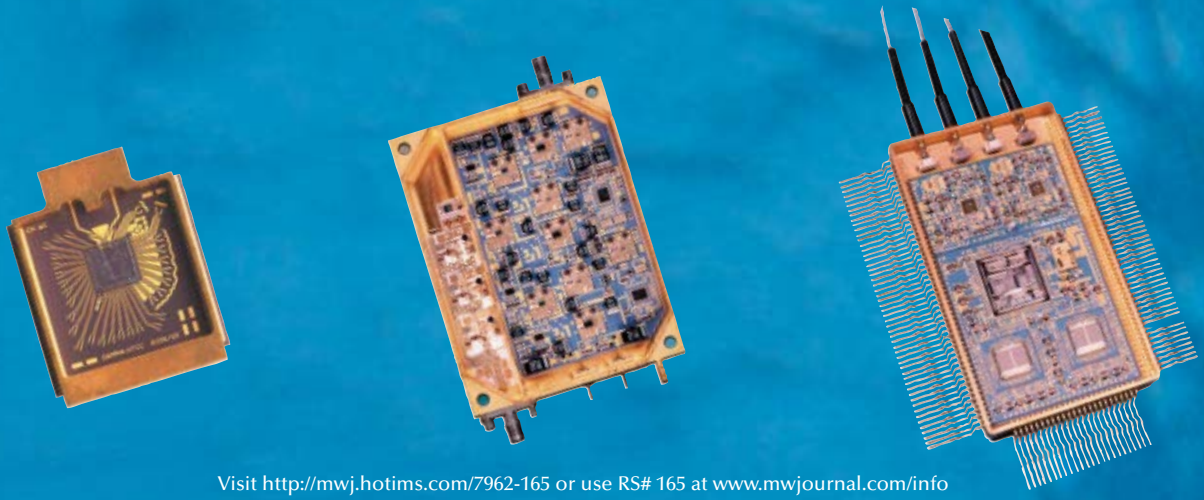

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increasing interest in exploiting mm-wave frequencies from 60 GHz upwards. The advantages of lack of spectral congestion, large bandwidths and small antenna size have always been challenged in the past by high component cost, including packaging but this is now beginning to be addressed by the remarkable progress in the high frequency behaviour of deep sub-micron Silicon-on-insulator technologies.

Significantly too, the high end automotive sector is of key strategic importance to Europe's economy and there is continuing interest in automotive radar systems at 77 GHz with the aim of dramatically reducing road injuries and fatalities. At much higher frequencies, there are intriguing signs in Europe that the terahertz region, long unexploited, is beginning to open up entirely new markets and opportunities.

Satellite technology has been strongly supported in Europe for civilian applications through agencies such as the European Space Agency (ESA), and the continuing deployment of the Galileo system over the coming years, working in conjunction with UMTS and personal communication devices, offers very interesting possibilities for new localisation services, even while the user is indoors.

Research in Europe takes place at national level, but there is also a strong cooperative research ethos in Europe developed over many years of EU Framework Programmes (FPs). The current 6th FP is supporting many large microwave-related activities including power amplifiers (TARGET), RF MEMS (AMICOM) and antennas (ACE). The new 7th FP will extend over seven years with a budget of about €54 billion and will be launched at the end of 2006. From the emerging shape of the technical content of FP7, wireless is everywhere both in terms of basic technologies and applications.

Overall, I believe the RF and microwave sector is exciting, growing and of mainstream strategic importance with excellent future prospects.

## COMPANY SURVEYS

### *ABF Elettronica*

Founded in 1986 the company's main activities are the design and manufacture of passive components such as filters, duplexers and microwave subsystems, and active components including up/down converters using thermo bonding, wire bonding and chip on board techniques. The main manufacturing is at its Italian headquarters but since 2004 the company has turned its attention to the new opportunities of integration provided by emerging East European countries. Consequently, it has recently built a plant in Romania, in conjunction with strategic suppliers with which it has been cooperating for several years.

Core activity is the telecommunications market in the frequency range from 450 MHz to 38 GHz, where it specializes in the passive elements for radio equipment and in passive microwave elements in general. In order to optimize costs the current emphasis is to carry out mass production for customers and to move away from the military market.

ABF's Alessandro Fossati believes that low cost materials and low cost production are key to development so long as they are allied to experience, skills and reliability. The training of skilled operators, leading to a quality product is just one example. He sees the telecommunications market with its desire for mass production at low cost being a driving force, with the momentum to move the market forward.

With the company's focus on former East European countries Fossati envisages political issues having greater impact with governments moving to create the social and technological infrastructure to attract manufacturers to set up business and stimulate home markets for the products being produced. On the flip side he sees developed countries, such as his native Italy, focusing on research and development, employing the better educated who demand higher wages.

### *Chelton Telecom & Microwave (a Cobham Avionics & Surveillance Division company)*

Dedicated to the microwave and RF field the company is structured into five distinct business units: the Systems business unit designs and produces subsystems and systems such as test benches, test generators and radars; the Diodes and Modules business unit develops silicon PIN diodes with low, medium and high voltage and RF modules such as attenuators, limiters, switches and mixers; the RF Filters and Duplexers facility designs special and standard air cavity filters, ceramic filters, and lumped element filters; the


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Ferrite Devices business unit manufactures circulators, isolators and sub-systems, based on drop-in, SMD, coaxial and waveguide technologies.

With such a large portfolio the company addresses four major markets — telecoms, medical, defence and space — with a very strong presence in the last two, which is mainly due to its vast experience and being part of Cobham plc. Key products in these industries are high voltage PIN diodes and ferrite high power isolators, which allies to the company's expertise in designing filters and duplexers for specific requirements with high rejection and low loss. The company utilises its engineers' knowledge in ceramic technology, lumped element filters and waveguide filters as well as air cavity filters and it offers the capability of integrating components into systems.

In Europe and Asia the company is involved in all major defence and space programmes: Rafale, Eurofighter and Satellite communications. Also all five divisions are encouraged to develop products for special market niches such as high voltage PIN diodes for MRI Systems, ferrite devices for telecom base stations and products for radio links.

Philippe Genin, CTM's general manager, sees the greatest activity in the space industry. He says, "It's a very dynamic area, with major developments still to be made in terms of increased power, surface mounted components, MMIC, circulator-isolator-limiter assemblies for phased array antenna modules and systems integration."

He identifies ferrite devices for the telecommunication market as a technology that will stimulate the market. He states, "This is a fast moving sector, where manufacturers must develop innovative technologies to stay competitive."

Geographically the company has identified numerous opportunities in the Asian and India region and has recently opened a sales office in Shanghaï in order develop local contacts with global manufacturers. Genin sees these emerging countries as a major driving force particularly in the communications market, citing the example of wireless technologies and the continued effort to strive for greater capacity and larger bandwidths. There is also growth in RF for automotive applications.

In his opinion geopolitics is a major driving force and identifies the Galileo global positioning programme as being particularly significant when he says, "The European decision to recover their autonomy and to develop their own earth observation systems, distinct from the American GPS has an impact in manufacturing. Today, all European manufacturers want to take part in this new development."

As for the future, Genin feels that the latest simulation tools for designing RF and microwave components and sub-systems means the company can access new R&D fields to achieve the three key objectives of space saving, power handling capability and low cost design. New materials are key points to meet these challenges; for example, SiC for semiconductors can be a solution for high power diodes or transistors, which can operate under extremely high tempera-

tures. Also, plastic, ceramic or carbon fibre materials remain alternative solutions to the metallic case when low cost products are needed.

### *Filtronic*

The company manufactures GaAs integrated components based on 0.25 and 0.5 µm pHEMT technology. The semiconductor products are manufactured on 6 inch wafers and are available in die form or packaged in a range of industry standard outlines. Both standard products and an open foundry service are offered. Also, using its proprietary MMIC process the company also designs and manufactures point to point microwave radio link transceivers and diplex filters for wireless backhaul in telecommunications systems.

Currently, most activity is in the cellular market sector, specifically multi-throw switches for handsets, discrete transistors, MMIC components and P2P transceivers for wireless infrastructure applications. This is driven by the high demand for mobile handsets in both developing countries and in developed countries due to 3G upgrades. WiMAX is an emerging market where 3.5 GHz MMIC solutions for CPE and infrastructure applications are offered. Traditionally the company also serves the defence market with integrated components for both EW and radar applications.

Technologically the cellular handset area is currently where the greatest activity is being seen and Filtonic's Wolfgang Bosch, CTO Filtronic ICS, UK, comments, "Increased complexity and functionality (multi-band, WLAN, WiFi, WiMAX, etc.) is driving the insertion of multi-throw GaAs switches into handset front-end power modules. In parallel with this is the fact that the overall cellular market continues to grow having a positive knock-on effect on the wireless infrastructure and the P2P businesses."

He also sees increasing demand for higher integrated GaAs MMIC solutions, switches for handsets and also for higher frequency microwave and millimetre-wave applications, together with low cost mm-wave packaging solutions.

Commenting on the geographical focus of activity Bosch says, "We continue to see the majority of the handset design work conducted in the US or EMEA with manufacturing being contracted out worldwide. In relation to the P2P business, the greatest activity is in the Asia Pacific and East European regions where cellular infrastructure is the optimum solution to interconnect mobile base stations. This is due to minimal existing fibre optic/leased line infrastructure and also the large distances that need to be covered. Also, Taiwan is very active at present in the WiMAX market."

With regards to new technologies and how they can help to stimulate the market, Bosch sees GaAs pHEMT technology as absolutely essential for today's and future handset front-end modules. He sees the increased functionality in cell phones and the roll out of the next generation communication networks (3G, 4G, WiMAX, etc.) resulting in a higher demand for GaAs. A key factor being the performance and cost advantage modern GaAs technology offers the communication market.

He explains, "Developing countries are extremely cost sensitive due to the low average revenue per user compared with developed countries. This translates to price pressure on equipment both in terms of acquisition and operating costs. The new technologies are stimulating demand by enabling significant price reduction, by increasing product reliability and through MMIC integration. Additionally the higher performance of new GaAs technology is enabling software configurable broadband links to be implemented at significantly lower cost points. This enables operators to upgrade the capacity of the network through software control without the need to replace the installed radio equipment."

The communications industry is also identified as being a major driving force due to the desire for increased data capacity and converged services, which is set to continue with initiatives such as WiMAX extending broadband coverage to laptops and similar terminals in a roaming environment.

### *Rosenberger*

The development and manufacture of RF technology products are the company's core activities and its product range includes RF-coaxial connectors in all common worldwide standards — SMP, Mini-SMP, MCX, SMA, N, 7-16, BNC, TNC, etc. — automotive connectors, test and measurement products such as precision con-

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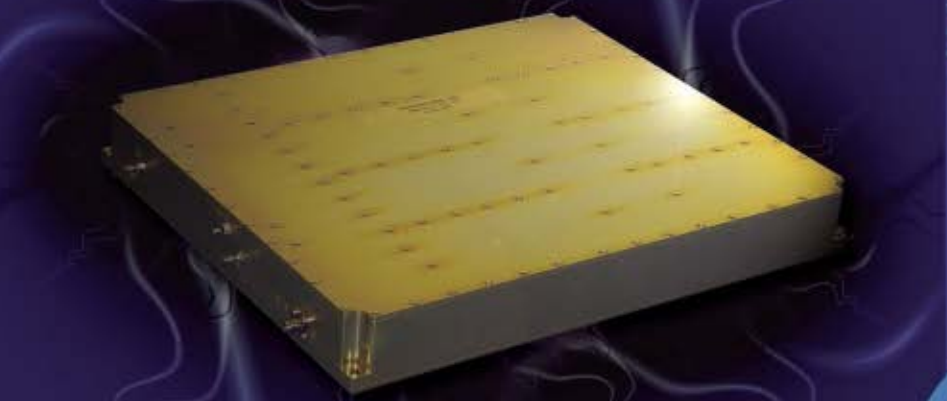

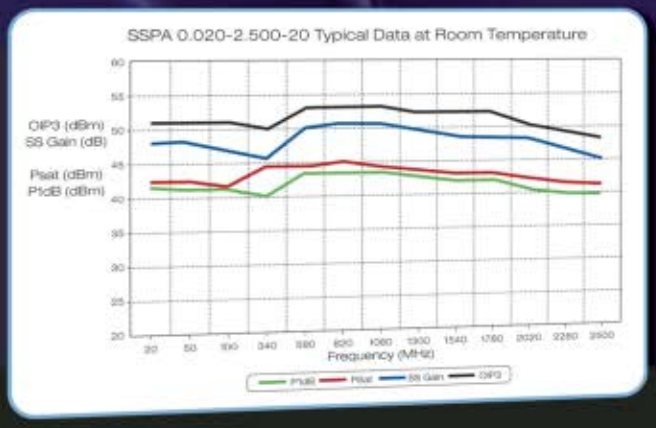


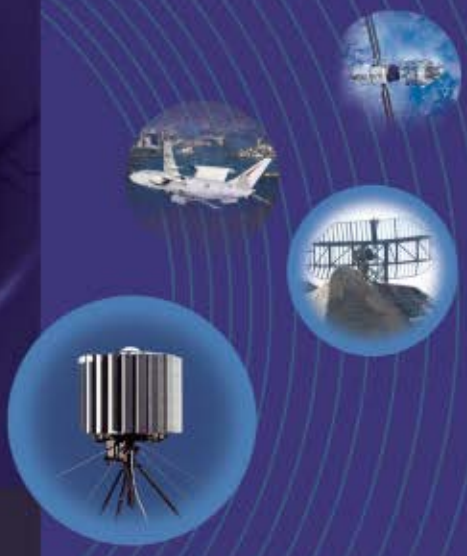

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nectors, test adaptors, test cables, calibration kits and attenuators, while cable assemblies are also available. In its recently established Wireless Terminal Components business unit Rosenberger offers spring loaded pins, adaptors and micro-RF test switches for wireless applications, mainly in consumer electronics or mobile phone terminal applications.

Key sectors of current activity include connectivity solutions for controlled impedance high speed data transmission, RF board to board connections, coaxial surface mount technology and, of course, the miniaturisation of components and systems.

The company's stated target is to develop RF products for a variety of state-of-the-art applications in all sectors of the electronics market. And in the future, it perceives the main fields of application to be in telecommunication, infotainment electronics and automotive electronics, along with aviation and military electronics and medical electronics.

Geographically the company envisages the fastest growing markets to be in Asia, particularly in China and India, but it will also focus on key-account customers in the European and American markets. Technologically, the view is that the need for higher data rates in communication applications will stimulate the development of components and systems, which will be a major driving force.

The company takes environmental issues particularly seriously in its effort to continuously improve and optimize all manufacturing processes to offer maximum benefit to its customers. This quality responsibility includes being proactive in protecting the environment and natural resources, through endeavouring to avoid or minimize environmental pollution beyond the requirements of legal regulations. It specifically avoids or limits the use of hazardous substances such as lead, mercury, cadmium and others.

In the next few years Rosenberger expects that an important challenge that the RF and microwave industry will face, but which will also provide opportunities, is the merger of telecom and infotainment applications. Alongside, it expects to see: additional system integration, e.g. planar to coaxial transition systems and connectivity system solutions.

## WIRELESS TECHNOLOGIES

### *Sector overview by ECWT Chairman, Dr. Richard Ranson*

The record number of technical paper submissions for the 9th European Conference on Wireless Technology, with roughly half from within Europe and half elsewhere reflects the international activity in the sector. Particularly encouraging is to see contributions from traditionally strong telecommunications nations such as the US as well as emerging growth countries such as Korea and China.

Submissions to the ECWT technical programme closely mirror industrial and academic research and development efforts in wireless technology and while previously it has been synonymous with mobile phone technology, this year sees significant diversification where advances in high frequency electronics are now being applied to other distinct wireless com-

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munications applications and services. The whole range of wireless communications is in the spotlight, from the antenna, through microwave or mm-wave circuits for both transmitters and receivers to demodulation and coding.

To highlight specific areas where there is particular activity, there is intensive interest in the areas of filters and antennas, where the challenge is to achieve smaller size, without compromising performance. Of the several promising avenues of interest, those involving new materials and novel structures to achieve the required size/performance are exciting. There is also a clear focus on integration, where removing various interfaces and connections achieves the dual goals of minimising cost and maximising the use of whatever space is available

Another broad topic that continues to attract significant work is power amplifiers and linearization techniques. Novel and interesting device and circuit ideas are being developed to meet the challenges of power, linearity and efficiency applicable to all areas of wireless communications. Also, the latest developments in UWB, WiFi, WiMAX (802.16d/e), MIMO and 3G HSDPA /HSUPA are promising to deliver the broadband connectivity required to truly realise the multimedia dream at home and 'on the go'. Other growing areas of interest include location technologies (e.g. GPS), UWB, telemetry, telematics and cognitive radio.

2006 is projected to be the year for mobile TV and video with big announcements recently from the major handset vendors and operators planning trials and commercial roll-outs based upon DVB-H, DAB/DMB, MediaFlo and MBMS technologies. These trials have been ongoing around Europe and a good deal of useful technical and commercial data is starting to appear.

ECWT demonstrates that there is clearly continued progress in established topics where the primary emphasis is on mobile phone systems. Fuelled by that technology base and the resulting low cost of components from that industry there are a growing number of new ideas and applications coming to the fore.

## COMPANY SURVEYS

### *Huber + Suhner*

In the wireless sector the company's activities are concentrated mainly on antennas, be they picocell for cellular (2G, 3G+), WiFi, RFID, WiMAX or Dect, as well as the SL60, 60 GHz point to point radio. For all of these the company makes coaxial cables and connectors as well as for all kinds of communication applications in the commercial and defence sectors.

In particular the company is witnessing tremendous growth in the WiMAX market as it sees this new standard offering an alternative means of broadband access for consumers and therefore a way for smaller ISPs to compete with Telcos, generating movement in the marketplace. It sees real demand behind the hype surrounding WiMAX and is supporting customers with a full range of products — BTS antennas, CPE antennas, high gain point to point antennas, cables and connectors.

The company also supplies a specialized antenna portfolio for the RFID, UHF-RFID market, where the momentum to implement this technology is coming both from global shipping applications and in the retail supply chain. Both WiMAX and RFID are seen as having the ability to stimulate the market.

H+S's operation is global, depending on the product/technology deployed, but traditionally its main activities are in North America and Europe, with communications as a key driver.

As for many, environmental and political issues are impacting on the company. Although, as it is a passive component manufacturer, the RoHS was never a big challenge it is concerned about ever increasing raw material costs combined with political decisions like China limiting the supply of copper. The consequence being that it might again be more effective to manufacture in the Western hemisphere, close to the consumer.

Finally, over the next few years H+S believes that new software solutions, convergence, triple play and the use of IP (VoIP) will fuel the demand for broadband communication solutions and implementation.

### *Nokia*

The company needs no introduction as the global market leader in mobile devices and smartphones and additionally its wireless products include base stations for cellular systems. Its main activities are in the development of

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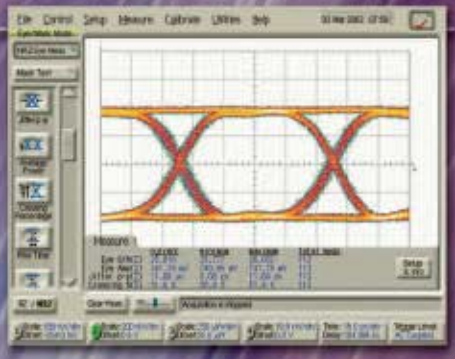

## APPLICATIONS:

- Optical communication systems where broad bandwidth is needed

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- Connectorized or true surface mount for lower frequency (30 kHz – 20 GHz) models
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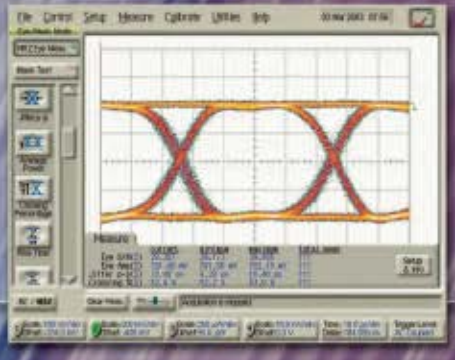

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next generation products for these markets but it is noteworthy that Nokia is also developing its own GSM/WCDMA chipset for its terminals.

The communications market is the company's focus, and with its combined mobile device volume in 2005 totalling 265 million units, helped by the excellent combination of power efficiency, miniaturization and performance in its mobile terminals, it is likely to remain so. Specific developmental activities are focused on antenna miniaturization and more configurable modem architectures targeting multiradio.

The market in which Nokia operates is fast moving and dynamic with manufacturers needing to be ahead of the game to develop those technologies that will fuel future market growth. Among those that the company has identified as being of particular importance are solutions for wireless broadband and multiradio including nanometer-scale CMOS-optimized RF and more power efficient heterogeneous BB processors, along with antenna miniaturization techniques.

Explaining in more detail, Petteri Alinikula, head of strategic research, Nokia Research Centre, says, "Architecture innovations are resulting from new technologies, which lead to cost, size and power reductions and therefore improvements in product competitiveness. For example, in wireless access implementation there have been several major technology steps during the last 15 years of cellular phone development, which have led to major improvements in miniaturization, integration and functionality.

"The next step is to take full advantage of the nanometer scale CMOS-technology in the RF front-end. Just mapping the traditional RF circuits to CMOS is not an optimum solution. With nanometer-scale CMOS it becomes practical to integrate extremely complex control and calibration circuitry with the RF circuits. The previous challenges in controlling parameter variations for optimum performance become easier to manage. On the other hand the traditional on-chip large passives, inductors and capacitors, become critically expensive. Consequently, new technology introduces new opportunities for the next step in architecture innovations."

The power management challenge is seen as being just as critical. Alinikula confides, "The fundamentally unique feature in small hand portable devices is energy economics. In small form factors the energy storage is very constrained. The energy capacity of batteries has grown at the rate of about 10 percent annually and no new technologies that would increase the energy density significantly faster are in sight. Moreover, the power consumption becomes constrained, because a certain size can only dissipate a limited amount of heat.

"Thus, maximum power levels depend on the heat dissipation characteristics for different device form factors and surface materials. As an example, the power budget for a small form factor hand portable with plastic covers is about 3 W. Accordingly, it is evident that heat dissipation capability is limiting the overall set of multimedia functionalities in the terminal. None of the subsystems is dominating the power consumption. Therefore, we need power management locally in all subsystems including the radios and system level global power management. It is clear that in the wireless domain, we need to continuously hunt for power savings."

## SEMICONDUCTORS

### *Sector overview by EuMIC Chairman, Steve Marsh*

As has been much publicised, 2006 heralds the inauguration of the European Microwave Integrated Circuits conference at European Microwave Week, which carries on from the highly successful GAAS® symposia. As its name suggests it will be focusing on all microwave integrated circuits based on any semiconductor technology from silicon, silicon germanium, through gallium arsenide, to gallium nitride, indium phosphide and beyond.

So, what are the major developments in this field? In terms of the semiconductor technology itself, we can expect to see silicon RFICs with SiGe transistors continuing to eat into the traditional GaAs MMIC market place but there is also an interesting counterpoint beginning to develop. In January Freescale Semiconductor Inc. announced that they had produced complete MOSFET transistors. This may just be a small step but both the Semiconductor Research Corp. and the computer processor giants Intel Corp. are actively trying to develop digital CMOS capabilities based on III-V compound semiconductors. When they succeed, GaAs microprocessors, memory and amplifiers will be fighting their way back into wireless systems and producing, for all we know, GaAs-only mobile phones.

Gallium nitride seems to be the other semiconductor technology generating a lot of interest within Europe. There are several large consortia working on this wide bandgap material, some funded by their own governments and others brought together under the European Commissions' Network of Excellence programmes. These large consortia are now working with extremely good quality material and we are just beginning to see an explosion of publications on GaN MMICs. Their impact on microwave and millimetre-wave power amplifiers for handsets and WLAN will obviously be huge but we may even see GaN chips taking over from LDMOS in base stations as well.

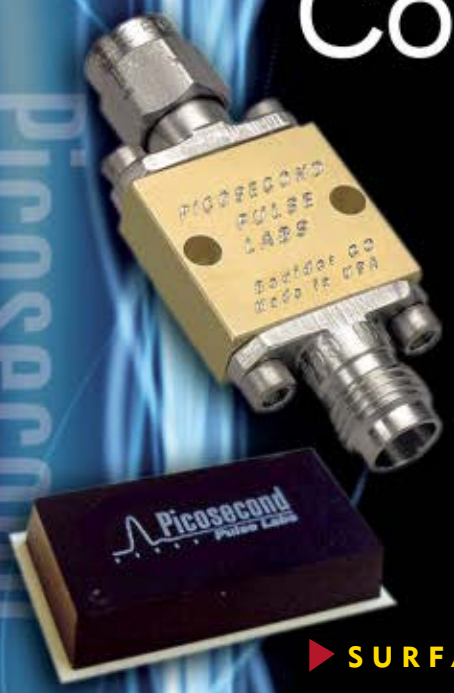
In terms of the businesses attending EuMIC such as the chip foundries and independent design houses, we are just coming to the end of a phase of MMIC capacity contraction and restructuring. The ITAR export restrictions have given the European businesses a small boost as the rest of the world seeks to obtain replacements for US chips in their developing systems from established European sources. The restrictions have also helped to accelerate the investment and development of semiconductor foundries within Asia, and as we see more and more facilities developed in India, Malaysia, Korea and China it will not be long before Asia's capacity will outstrip both Europe and the US. It's just as well then that the European Commission's NoEs are achieving their targets of grouping European business into pan-European partnerships so we can compete within this changing market.

In terms of growing applications for MMICs, we are seeing resurgence in activity in mm-wave and terahertz technology for several security system applications. Integration is a key driver to bring down system costs if they are ever to become commercial realities. One example is the need for multiplier and mixer functions on a single MMIC at 90 to 270 GHz, which may be possible sooner than you think with foundries favouring MHEMT as the way forward for InP MMIC progression.

## COMPANY SURVEYS

### *Semelab*

# Ultra-Low Phase Noise Comb Generators

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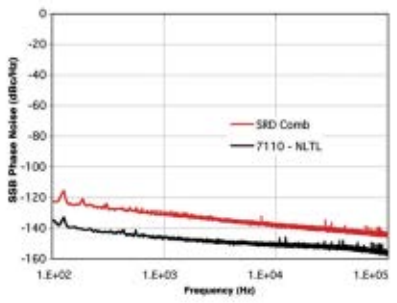
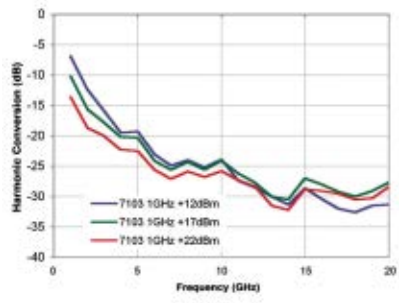


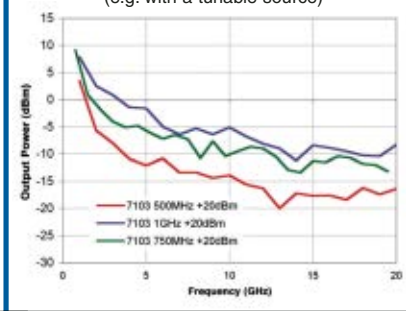

**Model 7110 and SRD residual phase noise comparison.** 200MHz, 19dBm input. Measured at 2GHz or 10th harmonic.

**Lower Input Power** simplifies amplifier requirements and reduces power dissipation




**Model 7103 conversion loss versus input drive power.** 1GHz, 12dBm to 22dBm inputs.

**Wide Range of Input Frequency** in a single device enables new applications (e.g. with a tunable source)




**Model 7103 output power versus input frequency.** 500MHz to 1GHz, 20dBm input.

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Established in 1974, this privately owned UK company's main activities in the microwave integrated circuits/semiconductor field revolve around RF power transistors, which it supplies to both commercial and military markets.

It is active in the US, Europe and the Far East, so has global reach, while technologically its goal is to strive for higher power, higher linearity, higher gain, lower thermal impedance, new packages, etc.

Dr. John Walker, RF Division Manager at Semelab, elaborates, "Technology isn't a driver in this market per se, customers are very astute and will only use new technology if it offers a clear benefit in terms of lower cost, better reliability, better RF performance, etc. However, this has to be allied to long-term commitment to maintain supply, immediate availability of product, full and comprehensive data sheets that don't change with time, etc."

With regards to the major driving forces on the microwave industry he says that they are always changing but that right now they are the likes of homeland security, digital broadcast, the new generation of military radios, and PMR.

He believes that environmental or political issues have a definite impact on modern manufacturing saying, "ROHS is a good example of both environmental and political forces driving changes in manufacturing. Also, there is a desire on the part of many organisations to lessen dependence on US technology due to export restrictions."

As for what will fuel growth in the microwave integrated circuits/semiconductor industry over the next few years, Dr. Walker's opinion is that wide bandgap technology will have a significant impact in certain applications such as ultra wideband amplifiers.

### *United Monolithic Semiconductors*

UMS is a III/V foundry offering a foundry service, catalogue products and ASICs. With its wide portfolio it serves various markets including telecommunications, focussing on microwave links (backbones) and high millimetre-wave applications. In the automotive sector the company covers 24, 77 and 79 GHz applications. On the military side it provides customers worldwide with products for applications in ground radars, active antennas, EW, communications, etc. It also serves the global space market and the ISM sector, mainly with sensors.

Particular areas of activity at present are in telecommunication, which is continuing to be lucrative following a very good year in 2005 and in the military arena where the company is involved in numerous major programmes. Geographically, the company's main customers are Europe and the US but it sees the shift to Asia being inevitable and ongoing if not as fast as perhaps was first expected.

Considering technological developments, Pierre Quentin, product marketing manager at UMS, comments, "2006 is the year for GaN to emerge. There is great R&D activity all around the world and the first products are coming onto the market. We have decided to follow this trend and believe that 2009 will be key for millimetre-wave products."

He also cites the emergence of the high band gap materials, such as GaN, that will facilitate higher power and better performance tradeoffs in terms of linearity, PAE, robustness, etc. Significant too are the silicon-based technologies such as the SiGe that are moving towards very high frequencies. Quentin comments, "In the coming years the microwave community will have to face huge changes brought about by these new technologies, but the GaAs PM-HEMT will continue to serve these market for a long while yet."

Quentin sees certain sectors seeing significant activity and says, "What is coming to the fore, riding on the never ending need for higher bit rates, is the provision of communication to the end-user segment (e.g. 60 GHz LAN) which will grab the attention of the consumer. The same is true for the automotive market, with huge pressure currently on 24 GHz sensors, which will very soon transfer to 77 GHz and maybe 79 GHz ones. Today, high specification cars are equipped with microwaves sensors, but soon it will be the case for all cars as quantities enter the more affordable consumer range."

For the future he sees consolidation of GaAs PM-HEMT, as a mature technology, with proven volume capabilities in production, with developments directed towards reducing the gate length to improve the performance, while emerging technologies such as GaN and SiGe will have a part to play.

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## RADAR

### *Sector overview by EuRAD Chairman, Patrick Beasley*

Since its inception in 2004 the EuRAD conference has gone from strength to strength with a record number of papers being submitted, demonstrating a thriving European radar community. It is also an indicator of activity geographically, so it is worth noting the significant representation from the Newly Independent States, most notably Ukraine, alongside the established West European countries.

The most significant recent trend in radar development has been the convergence between radar and communications techniques and technologies. This has been driven by the ability to design low power, solid state, CW-type radars taking advantage of low cost microwave components, up to I-band and beyond, together with the availability of high throughput, low cost signal processing capabilities, including optical signal processing which facilitate digital beamforming and space-time processing.

Radars are being developed that exploit communications techniques including MIMO transceivers, OFDM and ultra-wideband. In particular, the improvement in ADC sampling speeds and increase in the number of bits has moved the digitisation stage closer to the radar front end where dynamic range requirements are more demanding. Additionally, Direct Digital Synthesis (DDS) has provided a means to create waveforms of choice and facilitates coherent radar operation with the corresponding benefits of improved detection, simultaneous range/Doppler processing and clutter rejection.

There has also been a significant improvement in microwave and millimetre-wave oscillator sources in terms of ultra low phase noise and improved frequency stability which, again, facilitates coherent radar operation. Phase-locked DROs and low cost VCOs developed for communications applications are replacing traditional sources and there is a demand for increased radar bandwidth for improved range resolution, particularly for surveillance radars, and for low peak transmit powers. This highlights the importance of spectrum sharing and the use of 'orthogonal' waveforms to prevent interference.

Developments in millimetre-wave radar have accelerated in recent years with the availability of relatively low cost components developed for automotive radar and point to point communications and a rapid increase in demand for passive millimetre-wave imaging for security applications. These radars are finding niche applications such as runway debris monitoring, radar level sensing, high resolution imaging and robotics.

The concern about the environment has lead to significant research into radar remote sensing of the atmosphere from space, airborne and land-based platforms. This provides meteorological and hydrological information and the information can also be used to assist in aviation safety. Advances in polarimetric SAR are key to achieving this aim and there are significant research efforts currently being carried out in France, The Netherlands and Ukraine.

In the field of radar antennas the most exciting research is being carried out into conformal antennas, the use of

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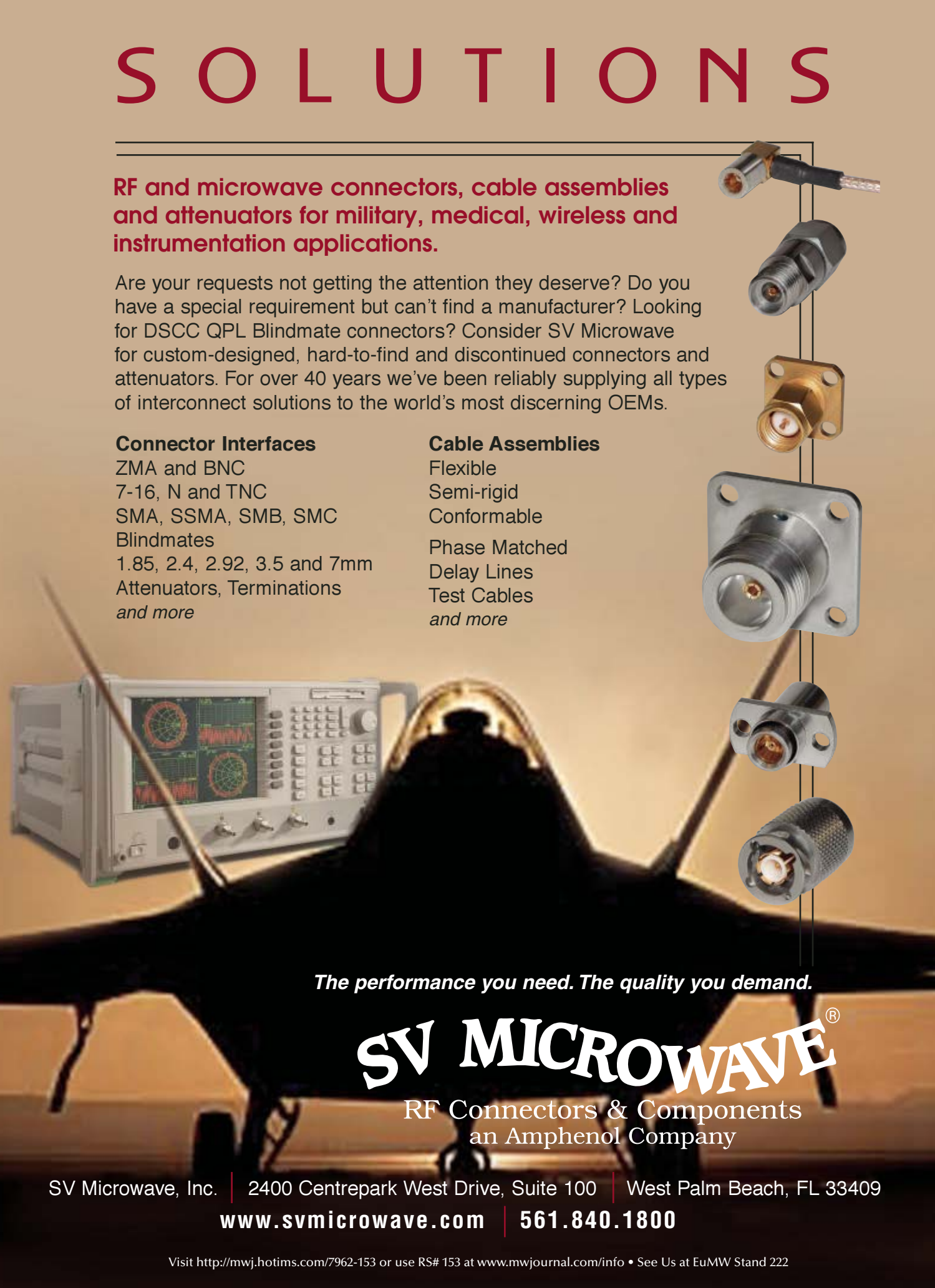

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metamaterials and plasma antennas. There is significant development into sparse antenna arrays which share common techniques with the radio astronomy community.

## COMPANY SURVEYS

### *EADS Defence Electronics*

As the Sensors, EW and Avionics House of EADS, the Defence Electronics Business Unit unites the sensor technologies for airborne, naval and ground-based platforms, providing components and subsystems based on the latest radar and electronic warfare technologies. It also develops and manufactures avionics systems as well as electronics for land-based defence systems.

In the microwave radar field the whole operational spectrum of multi-function fire control radars is covered — stand-off and penetrating surveillance and reconnaissance radars and navigation and terrain-following radars. Based on these products synthetic aperture radars, special purpose radars, seeker radars and multi-sensor integration are offered.

Specifically the company is addressing the future demand for sensors, electronic warfare and countermeasures, and communications generated by the movement towards a network-centric, information-driven operational environment. Dr. Hans Brugger, vice president, Equipment Engineering and Microwave Technologies, EADS Defence Electronics, comments, "The demand for products incorporating microwave technologies will increase significantly although the boundary of the analogue-to-digital conversion for antennas is moving closer."

He also believes that for radar, microwave based sensors, with their ability to cope with all-weather conditions both day and night, will continue to be the information gathering technique of the future, while in more advanced versions they will be backed by electro-optical sensors, imaging and lasers.

Brugger also states, "Microwave technologies will most probably be boosted by active array radars, namely Active Electronically Scanned Antenna (AESA) systems. The replacement of a tube amplifier by solid state technology, i.e. an array made up of hundreds to thousands of discrete transmit/receive modules using analogue integrated circuits (MMICs). Such radar sensors will provide significant performance improvements in terms of better range and target classification. The system also has maintenance life cycle cost benefits as the failure of single T/R modules would only marginally degrade radar performance."

He identifies significant industrial activity with regards to novel T/R-module packaging concepts, multi-functional integrated MMICs based on GaAs PHEMT and HBT technologies, ASICs on Si and SiGe. GaN is seen as an enabling technology for future robust amplifiers suitable mainly for high operating voltage, very high power and broadband purposes. Brugger says, "A modular architecture is necessary which allows higher levels of integration, reduced size, lower weight, and management of significant thermal budget."

He continues, "An integrated T/R-module design approach taking into account all relevant chip functionalities is necessary to achieve a components spread tolerant design for automated assembly and intelligent testing. Due to the dominant material cost a high first pass yield is mandatory during volume fabrication otherwise the cost target goals will not be achieved during the production phase. In this field the defence industry has to master the production of complex high-end components on a large scale as is the case in the telecom and automotive industry."

As for the future Brugger believes, "For the microwave industry the major driving forces will come from the active array radar and EW systems business, mainly due to transmit/receive modules and complex wide-band components, in that order. Likewise, the active phased array antenna technology will bring significant MMIC components business."

### *TNO*

Dating back to the 1930s, the Observation System Business Unit continues to experience significant growth in the area of military and space borne radar systems as well as commercial ones. In TNO's new organization, the vast majority of the observation system activities reside within TNO Defence, Security and Safety.

The company observes a trend towards low cost, flexible radar systems that can be developed in a relatively short time for low NRE costs. FMCW is becoming more and more feasible in a wide range of applications including very low cost systems for traffic con-





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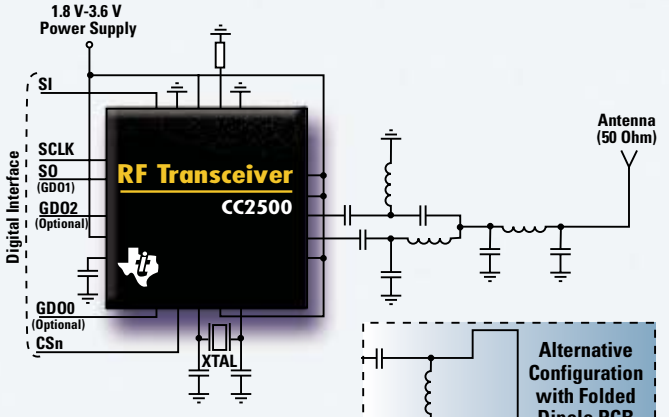


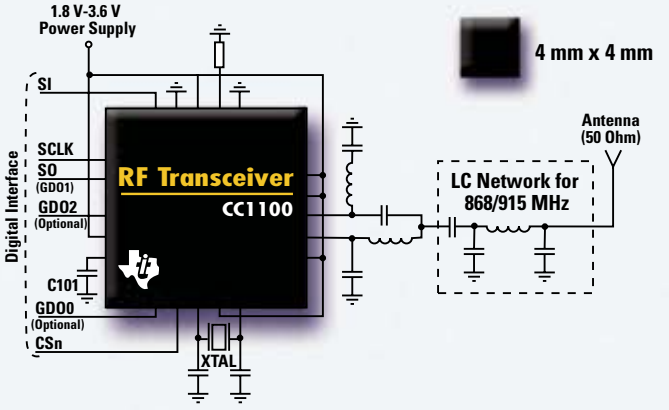


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trol applications for example, but also in synthetic aperture radars and in more complex military radars. The global international developments such as home and border security and coalition peace force operations require new radar architectures and fusion with a range of other sensors (optical cameras, IR, AIS, ESM) with an almost plug-and-play capability in various kinds of networks.

TNO's Dr. Frank van Vliet comments, "As a result, communication aspects are becoming more and more important and are thus increasingly being included as part of the radar. Simultaneous use of radar and communication waveforms becomes a feasible option. We believe future radars are based on modular, scalable and open architectures, which can only be achieved in a wide European initiative."

He also sees a trend for the continuing decrease in the cost of the microwave part of the sensor systems, mainly due to the III-V semiconductor manufacturing business maturing further as the playing field becomes truly global. van Vliet confides, "European technologies seem to be particularly well positioned, offering high-performance technology at ever decreasing prices. Bare-die approaches seem to find smaller and smaller niches, driven for a large part by consumer market plastic-type packages."

He continues, "At the system level, the application of mixed-signal SiGe technology into the radar's front end leads to an emerging new generation of radar systems — SiGe is not replacing III-V semiconductors but is bringing very new radar architectures within reach. Major breakthroughs in very cost-effective radar systems as well as in highly digitized radar systems are a matter of sustained development only."

van Vliet considers that at the component and sub-system level, threats of increased vulnerability to export limitations on systems employing US ITAR restricted components lead to a noticeable increase in the quest for alternative or second-sources, mainly in the military and the space borne radar domain. He believes that the competition to existing US component solutions is stimulated strongly by the ITAR, with programmes put in place in these domains by the respective governments.

As for the future, a renewed debate is expected around the application of RF CMOS versus BiCMOS technologies to microwave front ends; in order to circumvent the traditional problems with advanced CMOS in the noise floor and operating voltage (i.e., the dynamic range) by employing intelligent design techniques. van Vliet adds, "With the cost and capabilities associated with these technologies, even more challenging architectures will be serious implementation candidates."

At the radiator level, a shift in the R&D activities over the coming years is expected from current wideband activities into compact-oriented design techniques, combined with relatively low cost materials. Design techniques optimizing performance without affecting manufacturing cost will remain to be widely pursued.

## INTERNATIONAL PERSPECTIVE

Those are the views of those operating in and from Europe but does the 'outside world' share similar views? In the wider scheme of things is Europe a lucrative market for global RF and mi-

# "The most advanced traveling wave tube amplifiers got started on the back of a napkin."

*Ryan Pollace*
*ETM Electromatic, Inc.*

*AR Worldwide is relentless in its pursuit of solutions for its customers. If they don't have the answer, they'll find it.*

*That's how they found us, ETM Electromatic. About 11 years ago, AR saw a real need for traveling wave tube amplifiers (TWTAs) for high power microwave test applications. But they weren't really equipped to produce them. According to the story that's told around here, AR was having a 'blue sky' meeting with some of our people. They liked the way we thought. Both companies had a similar commitment to quality and innovation. And right there over lunch – on the back of a napkin – they wrote us an order to develop TWTAs.*

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crowave manufacturers? Is it ripe for investment? Is there potential for growth? And are there barriers to trade? To answer these questions we took a small snapshot of companies from across the globe. It is not claimed to be a comprehensive survey but is designed to give an 'outside looking in' perspective of how the European microwave industry and market is viewed worldwide. This report cannot comprehensively cover a large number of companies. However, it has canvassed companies in North America and Asia — Japan, Korea and China — to offer a contrast of established and evolving industries, household names and new market entrants.

## COMPANY SURVEYS

### *North America*

### *M/A-COM*

In the RF and microwave field the company's main focus is on the design and manufacture of RF, microwave and mm-wave components and assemblies for commercial, military and space applications. Current areas being targeted for development are emerging commercial wireless markets such as advanced cellular infrastructure, WiMAX and RFID in addition to selected military applications. In particular the company is investing in the development of RFID components and systems, telemetry transmitters/data links and mm-wave UWB sensors.

The company brings its wide breadth of products and more than 50 years experience in RF/microwave technologies, along with large quantity RF/microwave manufacturing capabilities to the European marketplace. To specifically address the European market M/A-COM works with leading wireless OEM's to design custom solutions and standard products for emerging wireless markets. As well as being active in the established markets of the UK, Italy and France the company is also witnessing growth in Eastern Europe.

Elaborating, Patrick Hindle of M/A-COM comments, "We think there are opportunities in the Eastern European countries that do not have well established wireless communication systems as an area of growth. We only participate in this growth through supplying components to the major European OEMs. There are also opportunities to expand our aerospace and defence business in the UK, Italy and France with our high performance RF and microwave components, antennas and cables."

Particularly in Europe, mm-wave sensors and lower cost integrated solutions are seen as technologies that will stimulate the current markets and enable new applications. Hindle explains, "We are designing lower cost microwave sensors for new applications. These include short range automotive sensors — back up alarms, blind spot warning, collision avoidance, parking assist, etc. — with the potential for new applications such as security and automation."

The company is expanding its portfolio of rugged, miniature telemetry transmitters beyond projectile applications to other high performance areas such as aircraft stress testing, UAV data communications and industrial monitoring applications.

The RFID market is also a target. Hindle proffers "We see opportunities for RFID reader components and RFID systems, so are designing integrated RF components for reducing RFID reader cost and size while improving perfor-

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mance. At the same time, we are leveraging our RF technology to supply completely integrated antenna and reader stands for turnkey RFID systems. We see the RFID growth coming from supply management solutions first and then expanding into point of sale applications in the future.

Asked to comment on the trends that will influence the European microwave industry over the next few years Hindle singled out integrated MMIC and system-on-chip solutions, which he believes will enable new affordable applications.

### *TriQuint Semiconductor Inc.*

With all of its market core competence within the RF and microwave sector the company's markets span four major areas: handsets, military, base station and broadband, not forgetting a separate Merchant Foundry business that serves customers in Europe, Asia and the Americas. It is not surprising for this GaAs IC manufacturer that the largest market it operates in is handsets, which accounts for 48 percent of revenue, followed by broadband with 23 percent. The latter includes WLAN and WiMAX, which are growing segments of the wireless business.

As far as its European operations are concerned, three of TriQuint's largest customers are located in Finland (handsets), Sweden (base stations) and The Netherlands (handsets). It serves many other European countries with products from all of its market segments and one of its largest merchant foundry customers is based in Europe.

One reason why the company prospers in the continent is that some of the world's largest users of GaAs semiconductors reside in Europe, but perhaps even more important is that, in general, it develops products to specific market needs and customer requirements. For example, the company is one of the most active developers of GSM/EDGE and UMTS RF front-end modules with its new generation of EDGE/GPRS modules being small and highly integrated.

However, TriQuint doesn't see itself as offering products and services its European counterparts don't provide but believes it follows a different business paradigm. The company leverages in-house technologies such as GaAs, SAW and BAW to provide product solutions that other companies (European, Asian or American) can't offer because they don't have the same technology, or the ability to offer the same degree of high-level integration. This enables it to avoid passing along the 'stacked margins' others are forced to deal with due to the lack of one or more essential in-house technology.

It also utilizes its technology to provide high performance components including RF power amplifiers and integrated modules, RF/IF signal filtering, RF switching, integrated passives, and single package RF front-end modules with low part counts.

As for the future the company's view is that the proliferation and strong growth in personal broadband wireless applications including 3G, WiFi and WiMAX will continue to increase the compound semiconductor component opportunities, while emerging markets such as automotive radar are seen as having the potential to provide the next high volume market for RF and microwave technologies.

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### China

### Tiger Micro-Electronics Institute

Since its inception in 1991 the company has been a leading producer of quality microwave components and integrated assemblies for the military and commercial markets including the demanding commercial telecommunications infrastructure segment.

Known for its high quality RF and microwave components it offers power dividers, mixers, VCOs, RF amplifiers, couplers, hybrids, filters, rotary joints, isolators, circulators, pin switches and phase shifters in a variety of robust mechanical and interface configurations covering the DC to 18 GHz frequency range. It also utilises its design and manufacturing experience to produce custom designs to customer specifications.

Due to the boom in the cellular and wireless sector the company is particularly active in wireless communication and is taking advantage of the low operating costs of its ISO 9001:2000 certified manufacturing facility to provide competitively priced products to its customers worldwide.

Tiger has been an OEM supplier to North America and Europe for many years, with France, Germany and Italy being key European markets. The company sees itself as having the levers to satisfy the needs of customers, be it in terms of meeting specific frequency requirements of a country or region or through offering fast delivery and flexible customisation to meet individual needs. The latter is particularly pertinent to military customers.

### Japan

### NTT Advanced Technology

Describing itself as a 'technology integrator' NTT-AT was established exactly 30 years ago. Since then it has drawn on its technical expertise, product development skills and know-how to create products and services that are based on leading edge research and development at the NTT Laboratories. The advent of the multimedia age caused the business to expand rapidly and it now covers almost the entire range of information and telecommunications technologies, including a variety of research/consulting services, sales of new products and system/network integration services based on state-of-the-art technologies.

The RF and microwave field is mainly served by the Nanotechnology and Materials Division. It offers expertise in the most advanced technologies shaping the future of broadband communications, from electronic devices to microfabrication and thin-film deposition technologies, and materials analysis.

There is significant activity focused on the field of III-V epitaxial wafers (InP, GaAs, GaN) for high speed electronic devices and RF-MEMS technology and nanotechnology with research and development for electronic and optical devices being at the forefront.

NTT-AT believes that in this increasingly competitive world, companies must take a hard look at issues such as how to create new markets and how to develop and introduce competitive products and technologies. To this end it intends to utilise its cutting-edge technologies and expertise to actively seek alliances with top high tech companies around the globe.

Europe-wide it intends not only to focus on high tech companies but also on research and development organizations and universities and believes that its products can support new technologies for the next generation mobile telecommunication and optical fibre telecommunication.

The company feels that, in particular, it can bring to the European market leading edge III-V epitaxial wafers for high speed electronic devices, especially GaN epitaxial wafers on various substrates. It also sees the future as demanding high efficiency and low power consumption devices and components.

### Korea

### RFHIC

Primarily targeting the wired and wireless telecommunication and broadcasting markets for its active RF components and modules, the company's strength is in providing solutions for applications below 5 GHz. All processes, products and services emanate from one facility providing good quality control and high reliability at low cost, with the ability to mass produce various high frequency components for the base station, repeater, cable network, digital TV, medical, optical and test equipment markets. It provides solutions from MMIC to hybrids and using its own components

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and design capability produces low cost, high performance custom developed modules and subsystems.

Currently the focus is on providing a full solution for WiMAX applications, offering MMICs, transistors, hybrids and power amplifier modules for both 2.5 and 3.6 GHz WiMAX applications. The company believes that the potential for WiMAX to combine standard wireless communications, fixed and mobile, in a broadband format for increased penetration for various commercial applications will increase the average selling price for service providers, which is the biggest selling point for equipment manufacturers.

The company has identified a market for medium sized, pallet type power amplifiers aimed at BTS and other infrastructure system manufacturers. Currently under development and soon to be released are 75 and 140 W power amplifier pallets for 3.6 GHz WiMAX applications with plans for lower frequency devices to follow.

As for its activities in Europe it operates in the major countries including Germany and France, along with Scandinavian counties and many in Eastern Europe. Its customers in Western Europe tend to be the larger companies, with the military oriented being dominant. In Eastern Europe although its customers tend to be smaller, specialized manufacturers operating in various markets they are usually leaders in their region. The intention is for RFHIC to use its strong customised development capabilities, representative network and new devices and products to target smaller leading companies in specific local markets.

As a component manufacturer, the company designs components depending on frequencies and believes that with coverage from DC to 5 GHz its active devices and modules for the mass communication market hold a strong position in all of the major commercial markets, including Europe. RFHIC is also building hybrids and modules using GaN technology, which with its high breakdown voltage, wide bandwidth and high output power at higher frequencies is well suited for WiMAX applications. Significantly, European customers are some of the first to apply this technology because many infrastructure system manufacturers are located there.

RFHIC believes that it can utilise its design knowledge to provide creative hybrid solutions and modules to European customers as rising costs and price pressures from the service providers mean system manufacturers must look for low cost yet high quality alternatives.

As for the future the company is taking a keen interest in which telecommunication technology comes to the fore. It believes 3G technology is definitely going to move up and 4G will enter the market but feels it will be interesting to see which technology is better poised for mobile and fixed wireless broadband internet. However, it is putting its faith in WiMAX to meet the demands of the European market.

## CONCLUSION

The European microwaves market is a complex web of interdependencies between highly specialist component manufacturers, subsystem manufacturers and large scale equipment contractors and this article is not intended to provide a definitive analysis. Its inten-

tion is to give an insight into current activity, an understanding of the marketplace and identify future trends. This report began with three questions, so in essence what are the answers?

First, one of the realities of globalisation is the low cost mass production competition emanating from Asia and other emerging countries. To some degree Eastern Europe, with its cheaper labour and overheads, can compete and can be supported by mutually beneficial cross-European partnerships. However, as a whole, Europe's strengths lie elsewhere, predominantly in value added products and research and technological development. It has the skills, expertise and academic infrastructure to take a lead and profit from the opportunities that globalisation offers for growth in existing markets and for conquering new ones.

To do so means ensuring that technological developments and innovations are commercially viable with the structures in place to take them to market and make the most of their earning potential. The European Union is united on these issues and is implementing its strategy to deliver growth, competitiveness and employment. Its main medium for achieving this is the EU Framework Programmes, which identify key areas of R&D and organise and fund specific pan-European collaborative projects. Through the Networks of Excellence Programmes the RF and microwave sector has been a particular beneficiary and as the 6th FP makes way for the 7th this looks set to continue. This Europe-wide cooperative and collaborative ethos is coming more to the fore and reaping benefits. It is epitomised by the Galileo Project to create Europe's own global positioning service that is stimulating investment and technological advancement.

Finally, the depth and variety of the research and development work currently being undertaken does not make it easy to identify future technological trends. However, in the RF and microwave sector leading edge work is focusing on microsystems and nanosystems, while applications of higher frequencies in the mm-wave and terahertz ranges are also being examined. In the wireless technologies field high frequency electronics are being applied to distinct wireless communication applications other than mobile telephony as the demand for multimedia access and infotainment grows. For semiconductor technology silicon RFICs with SiGe will continue to eat into the GaAs MMIC market, while gallium nitride is generating great interest. But keep a watch on the development of digital CMOS capabilities based on III-V compound semiconductors. In the radar sector we will continue to see convergence between radar and communications techniques and technologies and developments in mm-wave radar finding wider applications. ■


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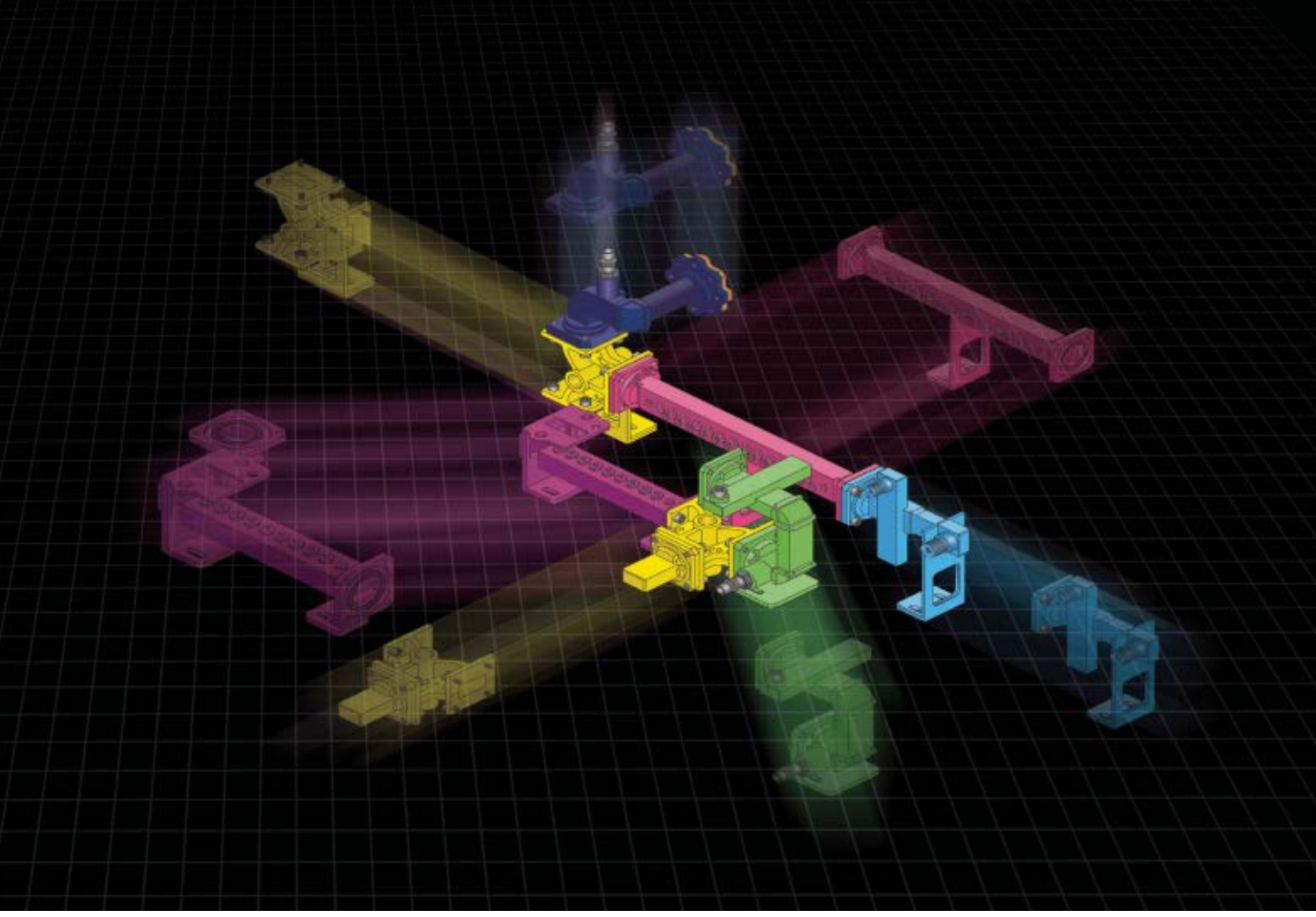

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# IMS 2006: Another Record Breaker

Ten years ago IMS 1996 set records as the largest IMS Symposium and Exhibition to date. San Francisco once again proved a great draw for our industry and its many engineers. IMS 2006 was indeed another record breaker, with over 12,000 total attendees and almost 3000 conference delegates registered. In addition, the characteristic San Francisco fog was a no-show. All in all, Microwave Week was a huge success and a rewarding week for all that attended.

Much of the credit for that success goes to this year's general chairman, John Barr, and his very capable staff, including Elsie Cabrera and the staff from IEEE headquarters in New Jersey. They are to be congratulated for their dedicated efforts and attention to detail that makes this event such a well run and rewarding experience. Thanks must also go to the Moscone Center and SFCVB staffs. They and their superb facility were gracious hosts and enabled our week's program to run smooth and efficient.

Thanks also to the general chairman of the 2006 RFIC Symposium, Stefan Heinen, and to Ken Wong, the conference chair of the 66th ARFTG Measurement Conference, and their able staffs. Both the RFIC and ARFTG conferences were equally successful and well attended.

## The Technical Program

This year's technical program was comprised of 246 oral presentations and 166 interactive forums. There were 55 separate program sessions and 42 workshops, with five panel sessions and an interesting rump session presentation by James Rautio celebrating the 175th anniversary of the birth of James Clerk Maxwell, attended by 600 individuals.

The program kicked off with two inspiring Plenary Session talks: "WiMAX and the Future of Mobile Wireless Broadband" by Ron Resnick, president and chairman of the WiMAX Forum; and Professor Richard White of the University of California at Berkeley, who spoke of "Nanotechnology: Hype or New Horizons."

As mentioned before, there were just under 3000 registered delegates attending over 1000 various technical presentations. The IMS Technical Program was co-chaired by APS (Paul) Khanna and Roger D. Pollard. By all accounts this year's comprehensive technical program was the most well attended and successful of any to date and remains the backbone of Microwave Week.

Jennifer DiMarco
and Frank Bashore
Microwave Journal *staff*

# Highlights of the *MWJ*/MTT-S


# Reception & Exhibition


## The Social Program

Kicking off the social side of the week was the RFIC Symposium Reception Sunday evening at the Moscone Convention Center Esplanade Ballroom and the traditional *Microwave Journal*/MTT-S Reception Monday evening, held this year outside in the Yerba Buena Gardens on top of the convention center's south side. An earlier threat of rain gave way to an absolutely beautiful San Francisco evening and a good time was had by all.

Other prominent social gatherings included the IEEE MTT Women in Engineering Reception, the Ham Radio Social and the Student Reception, all held at the Marriott hotel. A reception was held prior to the Maxwell Rump Session, also at the Marriott.

Wednesday evening was the traditional Industry-hosted Cocktail Reception and the IEEE MTT-S Awards Banquet. Among the individuals recognized for their outstanding contributions were Peter Staecker, who received Honorary ADCOM Life Member Recognition for his continuing leadership in society affairs, and Roger Pollard, who received the 2006 Distinguished Service Award for his significant and outstanding contributions to MTT-S and the microwave profession. Other awards included Eikichi Yamashita, the 2006 Microwave Career Award, Wolfgang Hoefer and Peter Russer, the 2006 Distinguished Educator Award, Peter R. Herczfeld, the 2006 Microwave Pioneer Award, Marian W. Pospieszalski, the 2006 Microwave Application Award, Ian Gresham and Emmanouil Tentzeris, the 2006 Outstanding Young Engineer Award, Timothy T. Lee, the N. Walter Cox Award, and Joseph A. Hagerty, Florian Helmbrecht, William McCalpin, Regan A. Zane and Zoya Popovic, the 2006 Microwave Prize.

For those attendees and their families that wished to see some of the area's better known tourist attractions, there were scheduled trips to Muir Woods, Alcatraz, Fisherman's Wharf, Chinatown, Golden Gate Park and a San Francisco city tour, as well as a tour to the Carmel, Monterey area.

## The Industry Exhibition

In addition to the impressive technical program offering during IMS 2006, there was the Industry Exhibition, held Tuesday through Thursday in the Moscone Convention Center. This year provided record-breaking numbers with 523 companies displaying their latest new products and services in 917

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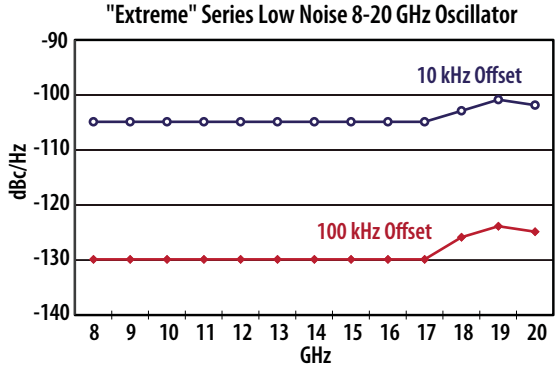


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booths on the show floor. A sampling of some of the exhibitors and their offerings follows:

ABF Elettronica featured both passband filters and duplexers at three different frequency ranges (2150, 2600 and 3500 MHz) for WiMAX applications. The first features a frequency shift (for DPXs) of 175 MHz and a 20 dB return loss bandwidth of 84 MHz. For the 2600 MHz version the frequency shift (for DPXs) is 74 MHz, with a 20 dB return loss bandwidth of 42 MHz, while the 3500 MHz version exhibits a 20 dB return loss bandwidth of 14 MHz. Also on show was the latest range of passive duplexer filters ranging from 4 to 38 GHz.

Aeroflex announced the new 3280 series, a line of 3 Hz to 26.5 GHz spectrum analyzers that are designed to provide performance far beyond the price tag, offering impressive RF and microwave specifications, exceptional connectivity and many ease-of-use features at an affordable price. This series offers a high level of accuracy, ±0.15 dB up to 3 GHz and other performance features that include good local oscillator phase noise < –115 dBm/Hz at 10 kHz offset from 1 GHz and +18 dBm third-order intermodulation performance.

Agilent Technologies had several new design and measurement solutions for advanced microwave, wireless research and development on display. Among them included several new capabilities for its PNA series network analyzer to simplify complex measurements for multiport and active device test. The new capabilities enable RF and microwave engineers to characterize components faster and increase production throughput while enhancing accuracy.

Agilent also announced the availability of an IEEE 802.11n MIMO modulation analysis capability for its 89600 series vector signal analysis software. Featuring a broad set of measurements, this capability is an ideal R&D tool for developers of MIMO-based IEEE 802.11n components, subsystems and systems, using general-purpose measurement tools.

The Agilent N4010A wireless connectivity test set (with option 107) supports Bluetooth EDR test mode, ensuring devices adhere to the Bluetooth 2.0 standard by enabling loop-back testing of EDR transmitters and receivers.

Also on display was the Agilent 3D electromagnetic design and verification software, EMDS, which is based on the Finite Element Method. EMDS delivers a full-wave electromagnetic modeling capability needed for characterizing 3D design geometries.

Analog Devices Inc. (ADI) extended its portfolio of RFICs with a dual detector/controller that precisely measures and controls the gain across the transmitter and receiver signal path within wireless infrastructure equipment. The ADL5519 integrates two matched detectors on a single chip, thus offering considerable savings in board area and component cost.

Also on showcase was a quadrature modulator that operates from 50 to 2200 MHz, making it well suited for

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low intermediate frequency and RF applications. Furthering its commitment to innovation in wireless and RFIC design, ADI announced an 8 GHz phase-locked loop synthesizer. The ADF4108 is targeted at high frequency wireless systems, such as those used for broadband wireless access, satellite communications, instrumentation, wireless LANs and base stations for wireless radio.

Anritsu Co. introduced the MT8222A BTS Master, a lightweight, handheld base station analyzer that provides wireless field technicians with a single test solution for installing, deploying and maintaining today's complex wireless networks. Weighing only eight pounds, the MT8222A BTS Master packs a complete set of tools that eliminates the need for technicians to carry several instruments in the field. Also featured in the Anritsu booth was the MS2781B Signature high performance signal analyzer, which integrates a full suite of physical layer measurements of both fixed and mobile WiMAX signals.

United Monolithic Semiconductor and Ansoft Corp. announced the implementation of a GaAs IC design methodology for millimeter-wave frequencies that utilizes on-chip electromagnetic extraction and a new Ansoft Designer®/Nexxim® RF design kit for the PH15 PHEMT process.

Applied Wave Research Inc. (AWR®) and Vector Fields Ltd. announced that they have integrated Vector Fields' Concerto™ three-dimensional electromagnetic modeling software into AWR's Microwave Office® circuit design platform. Vector Fields, experts in the field of EM modeling, offers a complete range of 2D and 3D EM modeling, analysis and simulation software that covers high frequency applications using modeling techniques.

Cree Inc. and AWR collaborated and announced the availability of a process design kit that supports Cree's high power silicon carbide process. The kit, announced during the show, enables MMIC designers to utilize Cree's MMIC process within AWR's Microwave Office software environment. Designers can now improve productivity by applying AWR's open and integrated design platform to Cree's wide bandgap SiC MMIC foundry services and discrete products.

AR Worldwide Modular RF's model KMW1031 booster amplifier was on display. It was recently field tested by the US Army at Fort Bragg and performed flawlessly. The amplifier was tested in a wide range of terrestrial and satellite system configurations. It was compati-

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bility tested with various Thales, Harris and Raytheon transceivers, and commercial Motorola repeaters. The KMW1031 is a 20 W, portable, lightweight, waterproof, fully automatic band switching RF booster amplifier that covers 30 to 512 MHz and uses filters to assure acceptable harmonic distortion levels.

Atmel® Corp. announced a collaboration with Wavesat to offer a WiMAX mini-PCI reference design that provides low cost WiMAX-compliant customer premise equipment. Developed to provide OEMs with a quickly deployable WiMAX end-product, the reference design will include Atmel's MAX-Link™ AT86RF535A 3.5 GHz WiMAX-specific transceiver, Wavesat's DM256 baseband, interfaces, all external filters and components, and software in a mini-PCI module. With an expected BOM of under $100, this design is projected to save OEMs 25 percent in cost and will be available in July.

Avago Technologies, a privately-held semiconductor company, featured a low cost solution for handsets that improves GPS receiver sensitivity to assure reliable satellite location of mobile phones. Avago's MGA-635T6 low noise amplifier module is designed for handsets for carriers that offer location-based services, and for meeting the US FCC Wireless Enhanced 911 mandate for handsets. This device also offers size and performance benefits throughout today's growing range of portable and mobile GPS-based applications.

Crane Aerospace & Electronics had on display satellite up- and down-converters for C-, X-, Ku- and K-bands. This satellite up- and down-converter family is designed to meet the demanding requirements of high speed data, TV and other analog and digital satellite communications needs. This series is developed to provide a flexible manufacturing configuration that allows the units to be rapidly customized for each client's specific application.

Computer Simulation Technology (CST) previewed a major new release of CST STUDIO SUITE™ 2006B including the 3D EM Time Domain tool, CST MICROWAVE STUDIO.® Research and development engineers involved in the design of high frequency components, wireless communications, EMC and signal integrity will now benefit from the augmented functionality and interoperability of the latest release of CST STUDIO SUITE 2006B. CST also previewed a new tool for the 3D EM simulation of electrically large structures at this year's MTT-S. The new Integral Equation Solver, based on the Multilevel Fast Multipole Method, joins CST MICROWAVE STUDIO's Transient and Frequency Domain solvers for high frequency applications and will be available in Q3 of 2006.

Dow-Key Microwave Corp., part of Dover Corp.'s Microwave Products Group,® now offers a complete line of 40 GHz RF switches. Designed to operate with high repeatability for both military and ATE applications, the newly introduced family of products provides users with a wide selection of 40 GHz RF switch options. The 40 GHz line includes SP6T multi-position coaxial switches, DPDT coaxial switches and SPDT coaxial switches. Dow-Key also showcased a compact SPDT PCB mount switch. The new 409 series unit, which can be mounted directly on an electronic board, is ideal for military, ATE and commercial applications that require higher power handling and greater resistance to severe environmental conditions. Its compact packaging occupies only 310 $mm^2$ of printed circuit board area to meet high density mounting requirements.

Building upon its industry-leading portfolio of WLAN power amplifiers, Fairchild Semiconductor introduced the FMPA2151, a highly integrated dual-band WLAN power amplifier module optimized to increase performance and reduce PCB board footprint in the latest 802.11a/bg WLAN applications. The high performance FMPA2151 offers 3.5 percent error vector measurement at 20 dBm output power, which helps to extend the wireless range in computing applications for worldwide Internet connectivity. This model saves designers up to 22 percent board space by combining 2.4 and 5 GHz power amplifiers into a single compact 4×4 mm package.

Freescale Semiconductor showcased its 2 GHz high power RF transistors that are housed in over-molded plastic packages and deliver performance comparable to air-cavity flange packages. The advanced devices will be based on the company's high voltage, seventh-generation RF laterally diffused metal oxide semiconductor technology. This advanced RF technology is designed to give designers of cellular infrastructure the ability to significantly reduce the cost of base station amplifiers, which are the most expensive elements of wireless systems, while maintaining stringent performance requirements.

Using newly developed high voltage RF power technology combined with over-molded plastic packaging, Freescale announced an expansion into the industrial, scientific and medical (ISM) market. Freescale is extending its technology and packaging leadership into the ISM market with transistors designed for both the HF/VHF frequency space (10 to 450 MHz) and the 2.45 GHz ISM band.

Hittite Microwave Corp. introduced an impressive 36 new products at this year's MTT-S, including three new leading performance product lines. The three new product lines included synthesizers, data converters and power detectors. The initial product from the synthesizer product line is the HMC-T1000A 10 MHz to 8 GHz dual synthesized signal generator. The HMC-T1000A is comprised of two independently controllable/programmable synthesizers, and combines ultra low SSB phase noise of –135 dBc/Hz at 100 kHz offset, with fast 10 microsecond switching in a standard 19" rack-mountable 3U chassis.

The HMC660LC4B wideband track-and-hold amplifier is the first product within the data converter

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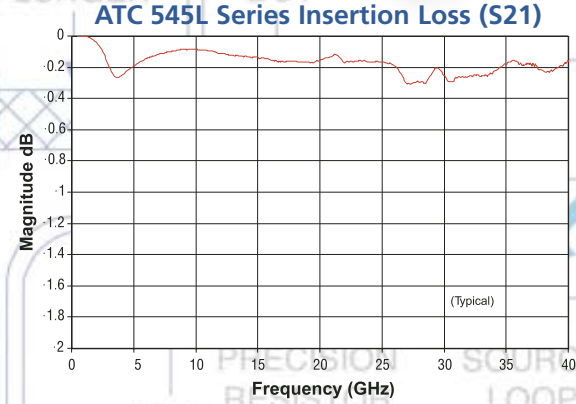
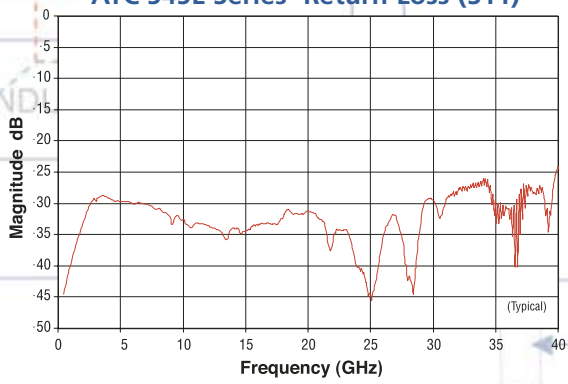



**ATC 545L Series Return Loss (S11)**




ATC's new 545L Series Ultra-Broadband Capacitor (UBC™)* is a unique component that provides ultra-low insertion loss, flat frequency response and an excellent match over multiple octaves of frequency spectrum in a one piece configuration.

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- Flat Frequency Response
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product line. Fabricated in a SiGe BiCMOS process, the HMC660LC4B is designed for direct sampling of full scale 1 Vpp signals with up to 4.5 GHz input bandwidth with a maximum 3 GHz clock rate. The HMC600LP4(E) is the first of a family of power detectors to be introduced within the new power detector product line. This logarithmic detector/controller is fabricated in a SiGe BiCMOS process, and delivers a high ±3 dB dynamic range of up to 75 dB, with good accuracy and temperature stability from 50 to 4000 MHz.

Huber+Suhner featured small, reliable, powerful, easy to handle RF power switches that require little maintenance and therefore are cost effective to use. The "plug and play" concept chosen by the company perfectly sums up this particular switch, which is quick, easy and convenient to install and operate.

K&L Microwave Inc., part of Dover Corp.'s Microwave Products Group,® introduced the bandpass/bandstop diplexer, which efficiently and accurately assists the out-of-band emission level measurements of wireless base stations. These measurements are conducted during the Federal Communications Commission (FCC) certification process. K&L also announced the availability of a family of microwave filters designed specifically to support original equipment manufacturers compliance with the FCC mandate to relocate incumbent BAS, CARS, LTTS licensees operating within the frequency range of 1990 to 2110 MHz. The company also highlighted high quality, innovative filter solutions that address evolving customer and regulatory requirements.

M/A-COM had several new items on display including two new 28 V LDMOS transistors ideally suited for commercial and INMARSAT applications. The MAPL-000817-015 is designed for commercial applications up to 1.7 GHz and provides 15 W, +28 dBm average power output at –39 dBc ACPR. The MAPLST1617-030CF is specifically designed for INMARSAT applications at 1.62 to 1.67 GHz, and is designed to provide 30 W, with 14 dB gain and 50 percent efficiency at 1.67 GHz and is housed in a ceramic package with a mounting flange. The company expanded its "RFID by M/A-COM" offerings announcing two new RoHS-compliant power amplifiers, the MAAPSS0095 and the MAAP-007649-000100, for applications requiring high power and high efficiency. M/A-COM also featured a RoHS-compliant SP3T diversity switch for applications requiring cross-modulation performance in the cellular and PCS bands while main-

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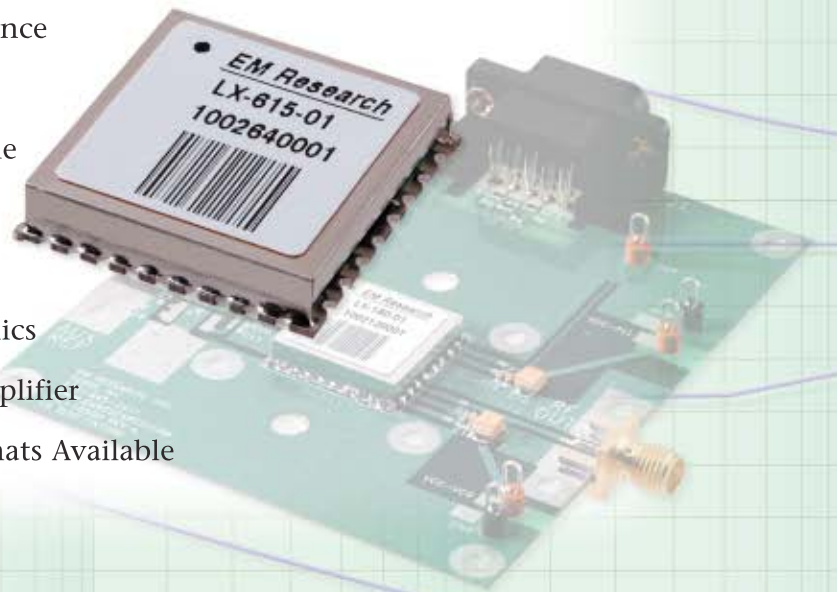


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taining good insertion loss and isolation. The MASWSS0191 is a high power switch with low control current, thus maximizing system linearity performance while simultaneously minimizing the Tx and Rx path loss. This switch is ideally suited for CDMA handsets as well as other applications that require switching to take place on a single antenna.

Mician GmbH introduced Version 6.0 of the company's EM-software tool μWave Wizard.™ The new release provides the seamless integration of 3D FEM simulation technology into the existing mode-matching and 2D FEM framework. This includes optimization, full 3D visualization of the electromagnetic fields, calculation of material and finite wall conductivity losses. The consideration of draft angles for die-casting technology and the modeling of arbitrarily shaped probes in cavities will be possible with new, flexible library elements.

Microsemi Corp. announced the addition of a high power, high gain medium pulse transistor to its line of products for S-band radar applications. Designated the 2731-100M, this transistor is a high performance, common base, class C, output stage offering 100 W of peak power, 40 percent collector efficiency, good 8 dB power gain flatness, and a hermetically-sealed high reliability package for air traffic control and military radar applications. Microsemi also featured a next generation wideband gap silicon carbide technology demonstration within its booth. The demonstration allowed users a first look at the silicon carbide RF power transistors for pulsed applications.

In addition, the company also announced a high power Mode-S, extended length messaging transistor designed for avionics applications. Designated the MDS 500L, the pulsed power transistor was designed at Microsemi's new RF Power Products division to provide 500 W output power with a high 55 percent collector efficiency and a 3:1 load mismatch tolerance for Mode-S applications in the 1030 to 1090 MHz frequency range.

Microwave Innovation Group (MiG) previewed the new version of WASP-NET prior to its release in July. In particular it now offers the capability for the accurate and efficient modeling of large slot arrays, including arrays up to 1000 slots, which makes it particularly suitable for defense applications. The new dielectric resonator library is based on the flexible Method of Moments (MoM) and is significant for the industry. Other new features include: 64-bit capability, microprocessor capability, an extended combline element library, a

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shaped subreflector antenna element, flexible 3D MoM elements, flexible 3D FEM elements, an extended number of subcircuits, a multi-frequency range option and a server version with new file handling capabilities, circumventing OP system dependent limitations.

Mimix Broadband Inc. showcased a GaAs chipset for X-band radar applications. This chipset includes a digital attenuator, phase shifter, driver and power amplifier. The XP1006 is a 10 W+ power amplifier that is offered in both bare die and packaged form. The XP1014 is a 1 W buffer amplifier that drives the XP1006. The digital attenuator and phase shifter, XA1000 and XS1000, respectively, provide good linearity performance with low phase and attenuation errors.

Mini-Circuits featured a series of frequency mixers that provide wide RF and IF bandwidths with high performance, small size and an equally small price. These SMA mixers cover broadband and multiband RF applications from 750 MHz to 15 GHz with an IF from DC to 4 GHz.

MITEQ Inc. introduced a new low noise block converter with a broadband fiber optic link, model LNBF-2440-05. The LNBF-2440-05 offers RF frequency coverage of 24 to 40 GHz and the internal local oscillator is set at 42 GHz. Applications include aircraft, shipboard, vehicle and antenna towers where reduced size, increased remote reliability and extreme environments are required. Also introduced was a new 18 GHz fiber optic link product, model SCM-18G. The SCM-18G Fiber Optic Link is a high dynamic range fiber optic link intended primarily for analog applications. This small size (< 1 cubic inch volume) product is fully integrated and requires no external support circuitry. It is successfully used in applications such as antenna remoting, EMC testing, RF on fiber, local oscillator remoting and others.

Pascall featured a new range of high performance OCXOs. The oscillators are housed in an SMA connectorized package as standard, with dimensions of 2" × 2" × 0.75". The standard range covers spot frequencies from 50 to 130 MHz with options on phase noise performance specifications. Pascall has developed its expertise of high performance oscillators and have new STALO designs for RADAR applications. These units are designed and constructed to meet the increasing demand for high performance oscillators. Excellent temperature stability combined with very low phase noise are key performance parameters.

Pascall also introduced the dual-loop PLDRO to the BP range. The Pascall BP2 PLDRO has been developed to offer a 5 or 10 MHz reference phase-locked source. This latest model offers exceptional performance and reliability in the range of 3 to 13 GHz with a DC power consumption of less than 2 W. These units are designed and constructed to meet the demand for high performance oscillators. All of the product introductions will be manufactured at the company's Isle of Wight facility in the south of England, UK.

Peregrine Semiconductor Corp. exhibited and promoted the launch of new RFICs. The PE42555 50 Ω broadband RF switch operates to 6 GHz and offers the fastest time to a fully settled state by eliminating the gate-lag. Also featured was the PE42742 75 Ω broadband RF switch that operates powered or unpowered and far exceeds the isolation requirement for the FCC 15.115 specification.

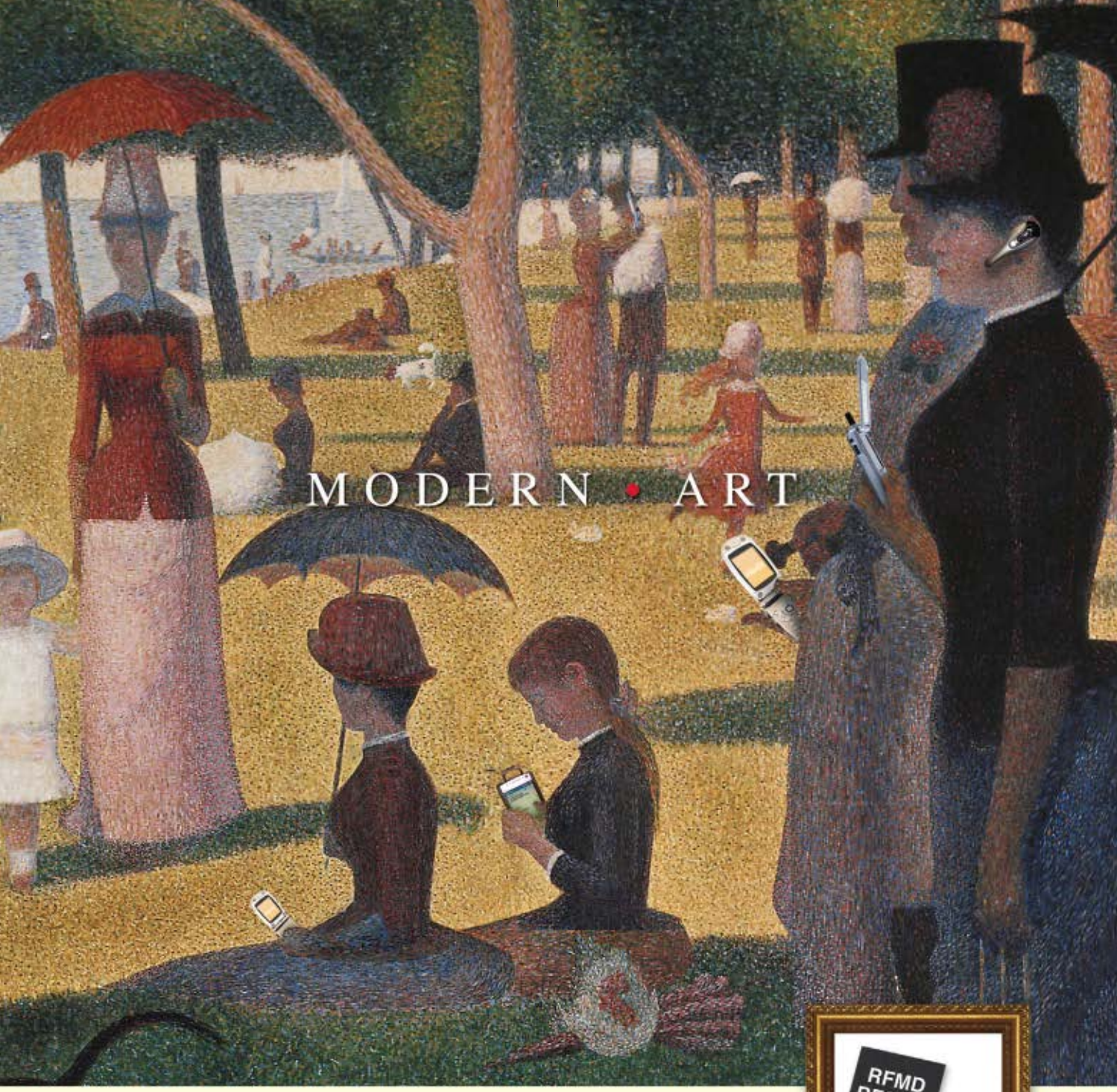
Royal Philips Electronics announced its next-generation LDMOS WiMAX line-up for base station solutions that delivers up to 3.8 GHz of performance over an 802.16e mobile WiMAX platform. Available immediately, the Philips Gen6 LDMOS solution enables the highest efficiency WiMAX in an LDMOS platform, offering users access to broadband communication anytime, anywhere.

RFMD® featured a family of GaN HEMT high power transistors and is currently sampling to top-tier cellular infrastructure and WiMAX base station customers. The sampling of these transistors represents the achievement of a baseline 0.5 µm GaN high power transistor process by RFMD.

RFMD announced that it has started pre-production sampling of five new GaAs PHEMT low noise amplifiers for GSM, CDMA, UMTS, EDGE and WiMAX air interface standards. These LNA products are currently sampling to key cellular infrastructure and WiMAX base station OEM customers and are targeted for production release in September 2006.

Rohde & Schwarz introduced several products including the R&S FSUP, the company's first instrument designed exclusively for measuring phase noise and characterizing RF signal sources. The instrument incorporates the company's many years of experience in developing high quality spectrum analyzers and low noise oscillators and synthesizers. This instrument combines a spectrum analyzer and phase noise tester that covers 8, 26.5 or 50 GHz.

The company introduced two options for the R&S FSL spectrum analyzer that expand its capabilities for Bluetooth and RF measurements in cable television systems. These included the R&S FSL-K8 option and R&S FSL-K20 option. Also introduced was the R&S AFQ100A I/Q modulation generator, which generates the complex digital modulation waveforms required to evaluate the performance of current and future wireless broadband communication systems. The instru-





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ment is an excellent choice for both R&D and production environments. Also featured was the FSH-K4 firmware option for its R&S FHS3 handheld spectrum analyzer that allows the instrument to perform standards-compliant 3GPP frequency-division duplex code domain power measurements on base stations. Also on display was the R&S SMA100A analog signal generator that provides good signal quality and short level and frequency-setting times in a compact footprint that requires only two 19" rack units.

Rohde & Schwarz also announced the R&S SMx-K49 option for its R&S SMU200A, R&S SMATE200A and R&S SMJ100A signal generators that allows them to generate signals in accordance with the WiMAX IEEE 802.16-2004 and 802.16e standards as well as the WiBro standards. The firmware also provides functions for receiver and component tests of WiMAX equipment. Also featured was the sixth and latest addition to the ZVA family of network analyzers, the R&S ZVA40. It is a 10 MHz to 40 GHz instrument and its operation at high frequencies means that it is suitable for applications requiring demanding RF performance, enabling the complete characterization of active devices, on wafer measurements and the measurement of harmonics and spurious. Performance characteristics include a dynamic range of > 130 dB/typical 140 dB (10 Hz IFBW, at test port) and > 150 dB (typical, 10 Hz IFBW, with direct receiver access).

Skyworks Solutions Inc. introduced a direct quadrature demodulator with integrated low noise amplifier for the 5 GHz band, delivering new levels of integration and performance for standard products in this spectrum. Given its simplified design, this solution facilitates access to various broadband applications in a low cost approach. The demodulator provides the flexibility to design receivers for various licensed and unlicensed broadband wireless data systems using low cost and low power direct conversion architecture. Skyworks unveiled a new ground-breaking ceramic packaging process that allows many of the company's existing linear products to operate at higher frequencies and with a smaller footprint. This ceramic solution is ideal for high volume, hermetically-sealed devices such as diodes that are used in WiMAX, military, space and a variety of other applications that require higher frequency operation.

Sonnet Software Inc. showcased its new Sonnet® Suites Professional™ Release 11 (slated for this fall). This release introduces a new type of calibrated internal port, which exhibits exceptional dynamic range. These ports can be used as accurate attachment points for transistors, diodes or other active components enabling full co-simulation of surface-mount parts and packages with planar EM analysis. Release 11 also introduces a redesigned seamless interface to the Agilent ADS Suite. The re-design, including an intuitive, easy-to-use GUI interface, runs in the ADS environment,

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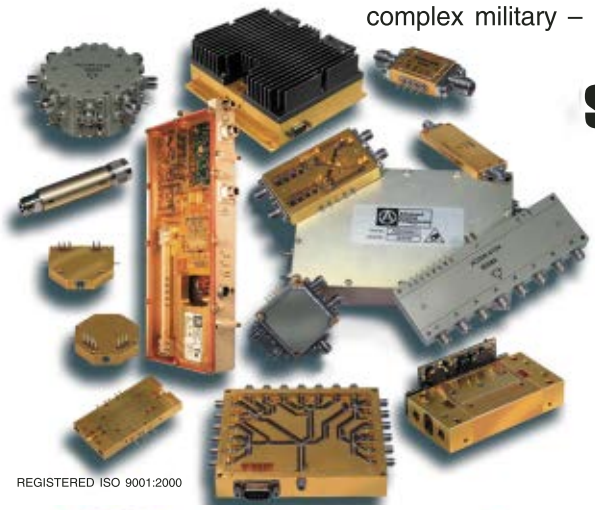

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which greatly simplifies the translation process. One can produce layout look-alike schematic symbols for using and sharing Sonnet models in ADS schematics.

SUSS MicroTec AG announced the newest member of its |Z| Probe® family, the |Z| Probe Card. This new solution integrates the unique |Z| Probe technology into an RF probe card specifically designed for production test. As RF and microwave devices become more complex and their operating frequencies increase, there is a significant need to extract scattering parameters on the production floor. These S-parameters describe the performance of the device under test and provide critical feedback for the manufacturing process.

SUSS also announced the release of the newest version of its wafer-level, high frequency calibration software. SussCal Professional simplifies the wafer-level calibration process and significantly increases the accuracy of on-wafer measurements.

Synergy Microwave Corp. announced the new DCYR and DCYS series of voltage-controlled oscillators (VCO) that make ideal YIG oscillator replacements. These VCOs are based on the company's proprietary patented and patents pending technology, which increases bandwidth, lowers phase noise and also highly improves immunity to phase hits. Also featured was the SGM series of wide bandwidth, surface-mount double-balanced mixers designed for up/down frequency conversion applications. The series is designed with multi-layer technology using embedded planar transformer structures, offering excellent phase and amplitude tracking for superior performance and low cost.

Times Microwave Systems has developed a DC to 18 GHz coaxial replaceable end connector for its Miltech® ultra low loss, lightweight cable assemblies, which can rotate 360 degrees continuously. This unique innovation solves many of the traditional problems of cable assembly fatigue failures due to constant flexing of high performance coaxial cable assemblies and also provides a viable alternative to using additional coaxial broadband rotating joints with their inherent poor electrical performances and high cost.

TriQuint Semiconductor introduced numerous new products during this year's IMS MTT-S exhibition. The model TGA4040-SM is a packaged wideband, medium power amplifier for 17 to 35 GHz applications including point-to-point radio, electronic warfare, instrumentation and frequency multipliers. The model TGA4525-SM is a packaged compact high power amplifier MMIC for K-band applications including point-to-point radio, SATCOM and point-to-multipoint communications that can also address the needs of emerging, cost sensitive markets. The model TGA2520 is a HPA MMIC ideally suited for Ku-band satellite ground terminal applications and point-to-point radios. The model TGA2602-SM is a packaged high IP3 dual PHEMT discrete low noise amplifier device designed for wireless communications network base station and WiMAX applications,

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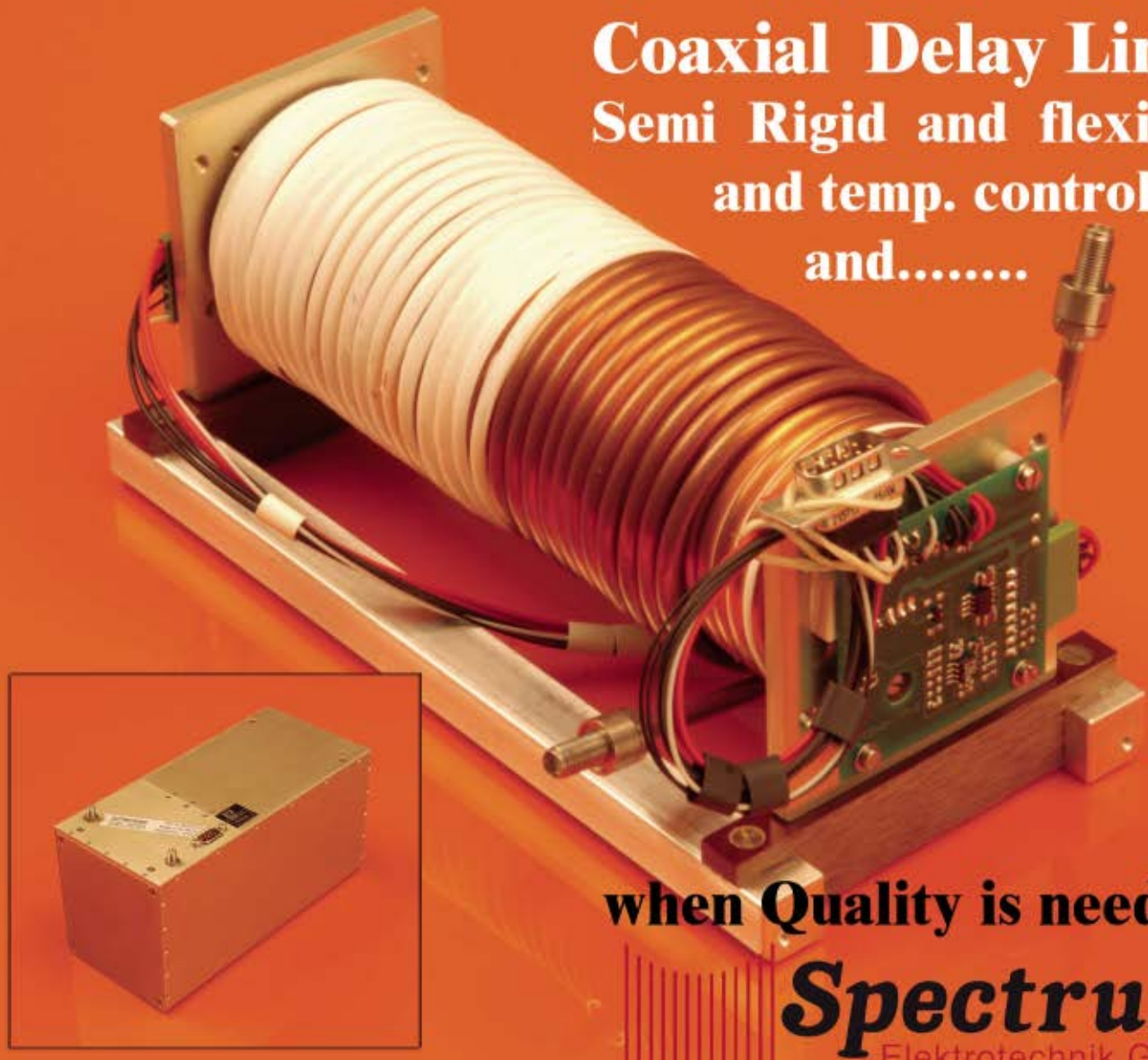

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operating from DC to 3000 MHz. In addition, TriQuint also introduced two new GaAs switches that offer designers high reliability switching in either double- or triple-throw configuration for use in multi-chip modules. The model TGS2302 is a SPDT GaAs switch built for operation in the 4 to 20 GHz range. The model TGS2313 offers performance similar to its SPDT counterpart, but in a SP3T configuration.

WJ Communications Inc. announced that it has developed a 28 V InGaP HBT technology for mobile infrastructure power amplifier applications. This technology provides significant advantages in power output and efficiency. Look for more detail on this WJ technology in our September issue.

This has been only a small sample of the new products and technologies that were showcased during the Industry Exhibition. We wish we could mention each and every one of them. However, space is always at a premium so please accept our apologies to the companies and products that have not been mentioned.

## HAWAII IN 2007

Many of you have expressed concerns about Honolulu as the site of IMS 2007. If you attended the exhibitor's breakfast on the last day of this year's show you are aware that many of the concerns are either not well founded or being addressed by the IMS 2007 chairman and his committee, and the Horizon House and Champion teams. Although travel and shipping costs are going to be somewhat higher for some, there are offsetting benefits in having this great symposium on the doorstep of Asia and its rapidly expanding marketplace. Much of today's RF and microwave technology is generated and utilized in Asia, and many of the industry's talented engineers reside in this region of the world. IMS 2007 will be an opportunity to more fully engage that segment of our industry in their backyard, so to speak.

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# EuMA

## The European Microwave Association

### What is EuMA?

The European Microwave Association (EuMA) is an international non-profit association with a scientific, educational and technical purpose. The aim of the Association is to promote European microwaves and to develop networking between microwave scientists and engineers in Europe. EuMA organises European Microwave Week, the most important microwave event in Europe, which comprises, besides the European Microwave Conference (EuMC), three more conferences in related areas — EuMIC, ECWT and EuRAD as well as the largest microwave show in Europe.

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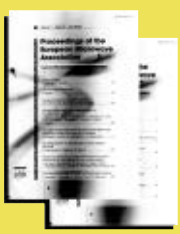

# APPLICATIONS OF CE ALLOYS IN DEFENSE, AEROSPACE, TELECOM AND OTHER ELECTRONIC MARKETS

The advantageous physical properties and manufacturing characteristics of Osprey Controlled Expansion (CE) alloys are currently being exploited in a variety of electronic applications. The ability to tailor the coefficient of thermal expansion (CTE) values of these alloys to ceramic circuit boards and components operating at high frequencies, combined with their lightness, high thermal conductivity, dimensional stability and manufacturability, have made them attractive for RF/microwave packages and carriers and also for heat sinks. The additional benefit of high stiffness has made the CE alloys with lower CTEs eminently suitable for optical and optoelectronic housings. On the other hand, the higher thermal expansion CE alloys are being increasingly used in carrier plates for laminate PCBs, guide-bars for circuit boards, and jigs and fixtures in semiconductor processing equipment and soldering ovens. This article considers how CE alloys offering these combinations of properties are being adopted for a growing range of applications.

Currently, CE alloys are finding increasing use in the electronics and allied industries for a variety of applications. These lightweight alloys are composed of silicon-aluminum (not AlSiC) and their CTE can be controlled to a chosen value between 7.5 and 20 ppm/°C, simply by adjusting the proportions of these two constituents (see ***Table 1***), making them compatible with many common microelectronic devices and substrates. A 5 ppm/°C grade alloy of 85Si-15Al composition is also under development.

CE alloys are typically between three and six times lighter than established packaging and base plate materials used in RF and microwave products and offer excellent thermal conductivity — a vital requirement for meeting the increased power loading requirements of the latest generation of devices and associated circuitry. They possess high specific stiffness, but are not unduly hard and so are amenable to standard machining operations, such as milling and drilling. Machining

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**TABLE I**

**STANDARD CE ALLOYS AND A SELECTION OF THEIR PHYSICAL PROPERTIES**

| CE Alloy Designation | Alloy Composition | CTE (ppm/°C, 25°–100°C) | Density (g/cm3) | Thermal Conductivity at 25°C (W/mK) | Bend Strength (MPa) | Yield Strength (MPa) | Elastic Modulus (GPa) |
|---|---|---|---|---|---|---|---|
| CE20 | Al–12% Si | 20.0 | 2.70 | | | | |
| CE17 | Al–27%Si | 16.0 | 2.60 | 177 | 210 | 183 | 92 |
| CE17M | Al–27%Si* | 16.0 | 2.60 | 147 | | | 92 |
| CE13 | Al–42%Si | 12.8 | 2.55 | 160 | 213 | 155 | 107 |
| CE11 | Si–50%Al | 11.0 | 2.50 | 149 | 172 | 125 | 121 |
| CE9 | Si–40%Al | 9.0 | 2.45 | 129 | 140 | 134 | 124 |
| CE7 | Si–30%Al | 7.4 | 2.40 | 120 | 143 | 100 | 129 |

*CE17M also contains minor additions of Fe, Mg and Mn

**TABLE II**

**RELATIVE BENEFITS OF SELECTED CE ALLOYS COMPARED WITH OTHER MATERIALS USED FOR HIGH FREQUENCY ELECTRONIC PACKAGES AND BASE PLATES**

| CE Alloy | Compared with: | Benefits |
|---|---|---|
| CE17 | Aluminum | 26% lower CTE, stiffer, 10% weight saving, excellent machinability |
| | Copper | less than 1/3 the weight, stiffer, stronger, same CTE |
| CE13 | Aluminum | 43% lower CTE, stiffer and lighter |
| | Copper | almost 1/4 the weight and stiffer |
| CE11 | Steel | less than 1/3 the weight, almost 3× higher thermal conductivity, same CTE |
| CE7 | Copper–85% molybdenum | 1/4 the weight, same CTE, cheaper |
| | Copper–85% tungsten | 1/6 the weight, similar CTE, considerably cheaper |
| | Kovar® | less than 1/3 the weight, 7× thermal conductivity, similar CTE |
| | Titanium | over 7× higher thermal conductivity, 1/2 the weight, similar CTE |
| | Al–65% SiC | easy to machine and electroplate, modest weight saving of 20%, similar CTE, no NRE costs for dies |
| CE7/CE9 | Be-BeO | CE alloys are non-toxic – only contain Si, Al, easier to strip off platings and rework/replate; similar CTE |

operations do not produce burrs on the higher silicon CE alloy parts, in contrast to most other metals, and this obviates the need for operations to remove them. CE alloys are also readily plated, using industry proven methods and being composed of silicon and aluminum, they are environmentally friendly, safe to handle and use, and present no disposal problems. Furthermore, as they do not contain strategic metals, such as cobalt, tungsten and molybdenum, they are far less susceptible to price volatility and supply shortages. Their unusual combination of high thermal conductivity and low thermal capacity, and the fact that heat is distributed relatively evenly, makes for easier soldering of feedthroughs. Because aluminum and silicon are light metals, soldered regions, comprising heavy metals, are readily revealed by X-rays, greatly facilitating nondestructive inspection of joints. Some of the relative benefits of CE alloys over alternatives are summarized in ***Table 2***. The beneficial properties of CE alloys are being exploited in a wide variety of applications, as summarized in ***Table 3***, and will be discussed, giving practical examples of their use.

## RF AND MICROWAVE PACKAGING

CE13, 9 and 7 are being widely used for microwave packaging for space and aerospace applications at operating frequencies as high as Ka-band (with an upper limit of 36 GHz), taking advantage of their reasonably close CTE match to circuit boards and components, their high thermal conductivity, low density, hermeticity, dimensional stability and ease of manufacture. While the CTE of CE11 is noticeably higher than that of alumina, which is widely used as substrates for microwave and RF circuits, it is far lower than that of aluminum. More pertinently, it is sufficiently close in its CTE to alumina for moderately compliant conducting adhesives to take up the mismatch stresses without compromising the adhesion or fracturing the alumina substrates. One example is a transmit and receive module, operating in the 3 to 30 GHz range with a housing of CE11, being developed as a replacement for one made of titanium used by Raytheon[1] (see ***Figure 1***). Titanium has a poor thermal conductivity and twice the weight of CE11; also, molybdenum-copper inserts have had to be introduced as heat spreaders to extract heat generated by active devices, which adds cost and complexity to their manufacture. By comparison, CE11 possesses a relatively high thermal conductivity, which enables the molybdenum-copper inserts to be dispensed with, at an overall cost reduction. The circuitry is mounted on alumina substrates, which are attached to the base of the housing with a conductive adhesive that is tolerant to the CTE difference.

Raytheon Space and Airborne Systems and Pacific Aerospace and Electronics, the packaging house, are also able to benefit from their ability to

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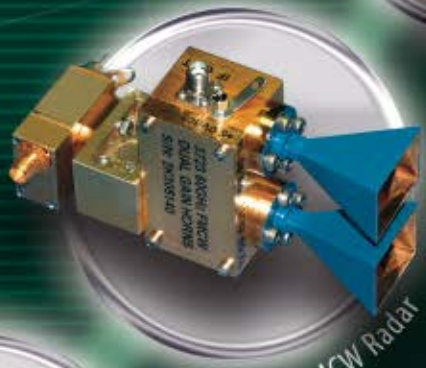

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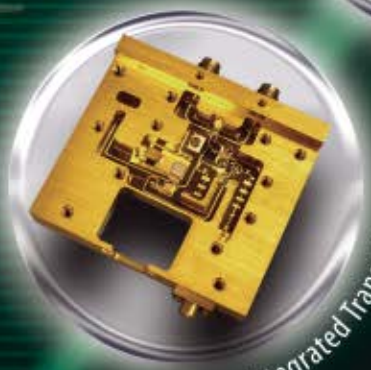

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**TABLE III**

**APPLICATIONS OF CE ALLOYS AND THEIR BENEFICIAL PROPERTIES**

| *Application* | *Beneficial Properties of CE Alloys* |
|---|---|
| RF/microwave packages and carriers | CTE can be selected for close match to circuit boards and components (e.g. CE7, 9) or to be sufficiently matched when using a compliant adhesive (e.g. CE11, 13, 17)<br>high thermal conductivity<br>light weight<br>hermeticity<br>dimensional stability, flatness, no/minimal burrs<br>manufacturability (machining and plating) |
| Optical and optoelectronic housings | CTE match to components (e.g. CE7, 9) or sufficiently compliant (e.g. CE11, 13, 17)<br>high thermal conductivity<br>stiffness<br>hermeticity<br>manufacturability (machining and plating) |
| Carrier plates for laminate PCBs | CTE match to PCBs (e.g. CE13, 17)<br>high thermal conductivity<br>cost and weight advantage over copper<br>manufacturability (machining and plating) |
| Guide bars for PCBs and embedded computer products | CTE match to PCBs (e.g. CE17M)<br>stiffness<br>light weight<br>high thermal conductivity<br>manufacturability (machining and plating) |
| Carriers for gas and other sensors | CTE match to electronic dies and sensor devices (e.g. CE7)<br>high thermal conductivity<br>stiffness |
| Heat sinks and heat spreaders | low CTE (e.g. CE7, 11, 13)<br>high thermal conductivity<br>cost advantage over W-Cu and Mo-Co |
| Lens holders in laser systems | high specific stiffness (stiffness/weight ratio) of CE9<br>close expansion match to lens glass |
| Semiconductor processing equipment | high specific stiffness (stiffness/weight ratio) (e.g. CE13)<br>high thermal conductivity compared with steels |
| Soldering assembly fixtures | good wear resistance compared with graphite (e.g. CE13)<br>good machinability<br>high thermal conductivity |

use a standard laser welding process for joining the aluminum sleeves of sealed feedthroughs to the packages and satisfy the requisite MIL-STD-883E specification on hermeticity. They have also verified that the gold-over-nickel plated CE11 packages pass the industry standard MIL-C-5541 salt spray corrosion tests.

CE13 has been chosen by Ericsson Microwave Systems AB as a replacement for Kovar® for a radar housing (see ***Figure 2***). The CE alloy offers the weight reduction required for this part (as the system into which it is incorporated rotates in use) and heat spreaders are not required. The circuitry is assembled on a CE9 carrier, machined with threaded holes and plated with nickel. This is then bolted down into the CE13 housing, which is also nickel plated, and the circuitry is tuned. Two lids of CE17 are fixed to the top and bottom of the CE13 housing to cover the screw holes, and laser welded in place to provide a hermetic seal. The nickel layer is skimmed off the joint areas to avoid compromising the mechanical integrity of the weld arising from nickel in the weld. The weld has been shown to be fully reproducible and allows for reworking.

Tyco M/A-COM has adopted CE11 for a hermetic microwave amplifier housing in aerospace applica-


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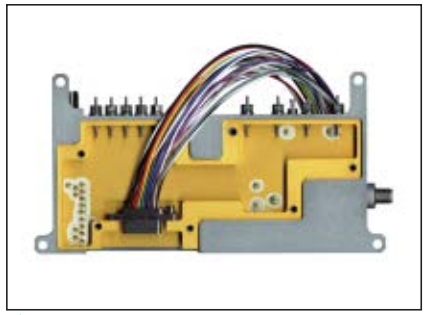

Fig. 1 Fully manufactured base of a CE11 package. (Courtesy of Pacific Aerospace and Electronics, and Raytheon Space and Airborne Systems)

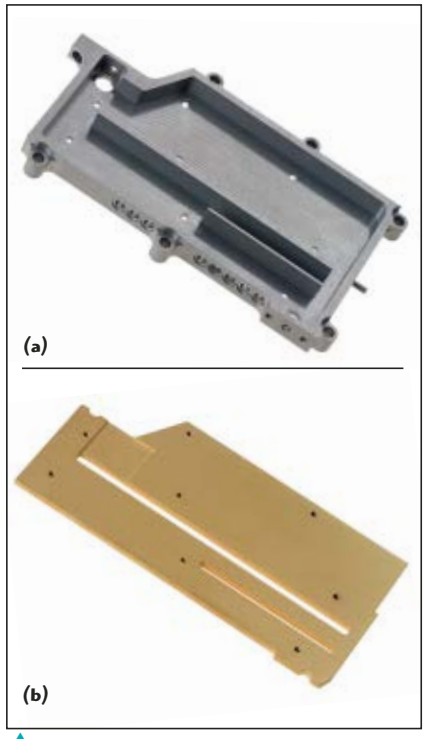


Fig. 2 CE13 housing (a) and complementary lid (b) in CE17 plated with gold, used for a radar application. (Courtesy of Ericsson Microwave Systems AB)

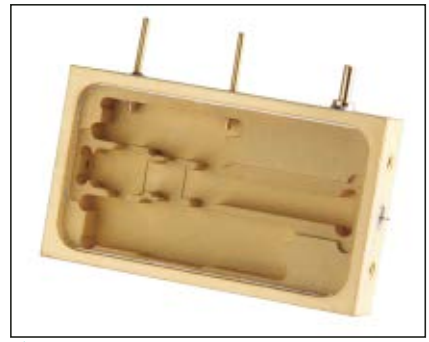

Fig. 3 Microwave amplifier housing for an aerospace application. (Courtesy of Tyco M/A-COM)

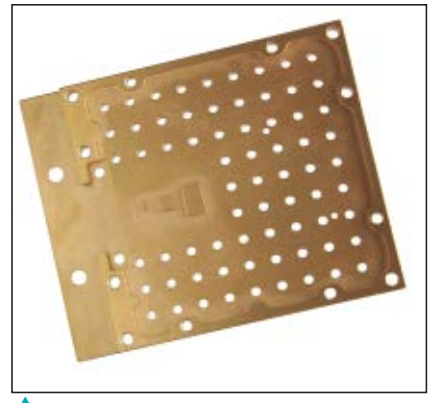

Fig. 4 CE7 transmit module carrier for 40 Gbit/sec operation. (Courtesy of C-MAC)

Fig. 5 CE7 optical housing for a switching device in an aerospace application.

tions, taking advantage of its lightness and not having to incorporate a heat spreader, thereby resulting in significant space saving (see ***Figure 3***). A steel shim is soldered to this package, and a steel lid is resistance seam-sealed onto it. This solution offers excellent reproducibility, resulting from the high consistency of CE11 and the associated processing, which is responsible for a high yield of this item.

## RF AND MICROWAVE CARRIERS

CE alloys are favored as carriers of microelectronic circuitry, in preference to copper-tungsten and copper-molybdenum, on account of their much reduced weight and cost. For example, C-MAC has gained these benefits by substituting carriers of CE7 for 10Cu-90W in Lucent's 40 Gbit/sec transmit modules. This has simplified manufacturing as, unlike previously, the carriers bear integral plinths for active microwave devices, which have to be located to a precision of 20 mm (see ***Figure 4***). This is achieved through the good machining characteristics of CE alloys, with the added benefit of high edge resolution of features and a high degree of flatness.

## OPTICAL HOUSINGS

CE alloys are also suitable for hermetic optical and optoelectronic housings, on account of their close

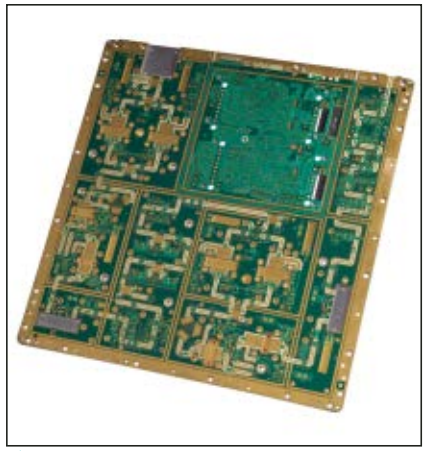

*Fig. 6 CE17-clad laminate PCB for a base station application.*

*Fig. 7 Guide-bars replacing tungsten-copper in a PCB used in aircraft. (Courtesy of Redstone Technology)*

CTE match to components, their almost constant thermal expansion over a normal range of operating temperatures, high thermal conductivity and stiffness, and good manufacturability. For example, ***Figure 5*** shows an optical housing in CE7, which forms part of a high speed MEMS switching device, comprising an array of these modules used in aerospace applications. The housing receives laser inputs and supports a series of mirrors supported by arms screwed into the walls of the housing. It replaces a similar item that was manufactured in stainless steel, which suffered from a number of drawbacks. CE7 provides a lower CTE, a welcome reduction in weight, improved stiffness and rigidity, and stays flat. The housing is plated with gold over nickel and during assembly is manually tuned by careful adjustment of the mirrors, which are then fixed in position by soldering the supporting arms to the housings. The stainless steel housings proved difficult to tune, owing to relative movement of the mirrors when soldering because the steel does not stay flat during the thermal excursion. By comparison, CE7 is dimensionally stable.

## THERMAL BACKING PLATES

Another application of note is the use of sheets of CE alloys (CE17 down to CE11) as backing plates to laminate PCBs formulated for high frequency use. These boards possess a polymer matrix, normally a hydrocarbon thermoset or PTFE (Teflon). They are filled with a ceramic to provide a tight control of dielectric constant, low loss and good temperature stability of dielectric properties. Additionally, woven glass reinforcement is added to improve stiffness and reduce the CTE in the x-y plane. CE alloy backing plates are available in sizes up to 20 × 20 inches, and down to 3 mm in thickness. Developments are also in progress to produce larger plates down to 1 mm thickness. Also, plates of up to 6 × 6 inches in area can be sliced to approximately 0.5 mm in thickness. CE17 provides an optimum solution for backing plate applications, as it is lightweight, and offers a good CTE match, high thermal conductivity and high specific stiffness. Its relative stiffness enables the laminate substrate to be made thin while remaining flat and thereby reduce microwave and RF dispersion and radiation losses. An example of a CE17-backed laminate board for a base station application is shown in ***Figure 6***.

## GUIDE-BARS FOR PCBS

Strips of CE17M are used as guide-bars for PCBs in aircraft and in embedded computer products, as a replacement for the same items in W-50Cu, being cheaper and only one-sixth of the weight. The CE17M grade alloy has small amounts of iron, magnesium and manganese added to the alumina-silicon, to improve hardness and machinability. The guide-bars in this material are stiff and match the CTE of the PCBs, and thereby reduce the CTE mismatch of solder-attached silicon devices, which also results in significant improvements to life fatigue. Recesses are machined on one side of the guide-

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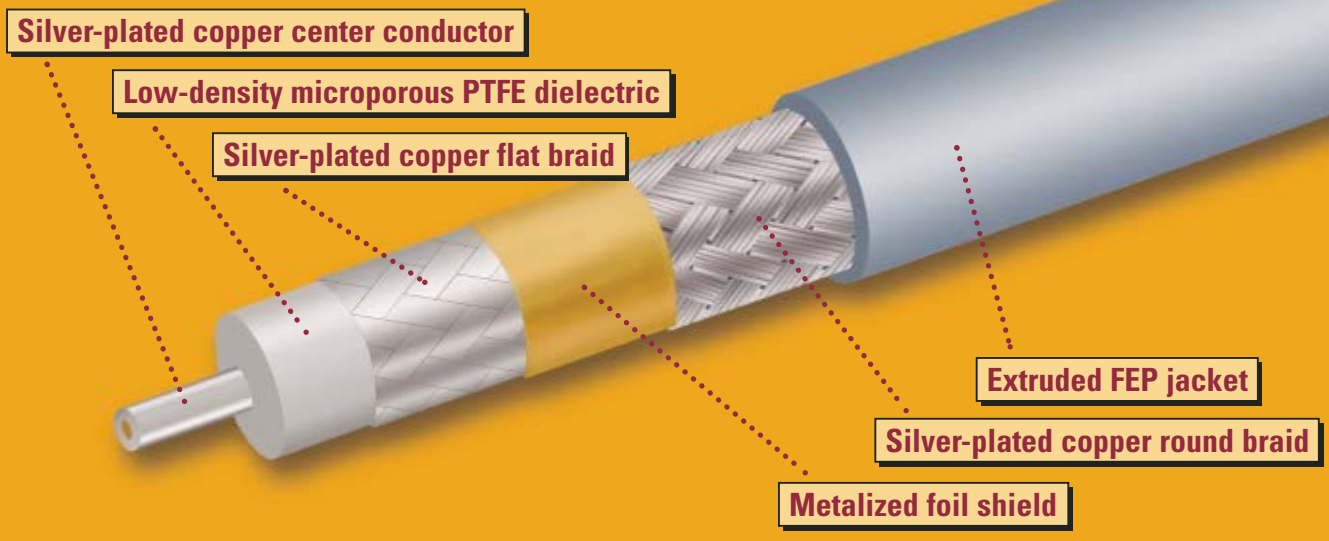


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bars, which are gold plated. Copper-clad projections on the PCBs are fitted into these recesses and soldered in place. The even side of the guide-bars is hard nickel plated for good wear resistance when the boards are slid into racks and then mechanically fastened down. Such guide-bars are illustrated in ***Figure 7***.

## CARRIERS FOR SENSORS

CE7 is being used in carriers for sensors, as a replacement for Cu-W. The specific benefits of the CE alloys for these applications are an excellent CTE match to sensor devices, high thermal conductivity to provide good heat sinking, stiffness, flatness and superior machinability to close tolerances, including crisp edges. In this application, a peripheral recess in the carrier has to be machined to a high finish, to house an O-ring for a vacuum seal, as shown in ***Figure 8***. This particular sensor is used in a mobile military application, where the weight saving over Cu-W is of major benefit. Other important applications of CE alloys include heat sinks and spreaders for power modules and discrete devices, and also microwave filter components, which take advantage of the beneficial characteristics enumerated previously.

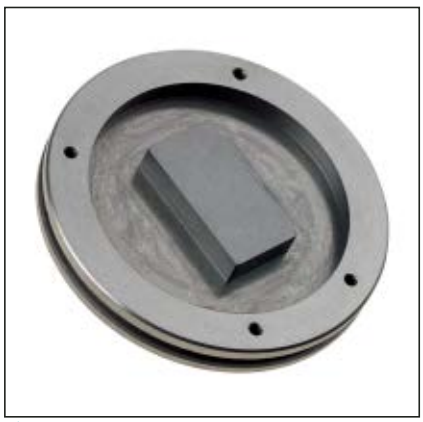

*Fig. 8 CE7 carrier replacing tungsten-copper in a lightweight sensor for a military application.*

*Fig. 9 Fixture of CE13 for soldering ball arrays. (courtesy of PTC Pte Ltd. Singapore)*

## PICK-AND-PLACE EQUIPMENT

CE13 is being used in pick-and-place assemblies in semiconductor processing equipment and other mechanical systems where low inertia is required. CE alloys are eminently suited for such applications, on account of their unusually high specific stiffness (stiffness/weight ratio) and low thermal expansivity.

## SOLDERING ASSEMBLY FIXTURES

CE13 alloys are also being used in soldering fixtures in flip chip and ball grid array (BGA) production lines. A fixture of the latter is shown in ***Fig-***


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*ure 9*. The controlled thermal expansion of these alloys at elevated temperatures is accurately predictable and helps in precise positioning and soldering of the solder balls in IC assembly lines. Its resistance to chipping and ease of machining to tight tolerances, in an application where high precision of feature definition is required, are beneficial. It also offers the further advantage of superior wear resistance, especially to graphite, which results in an enhanced service life and the combining of a high thermal conductivity with a low heat capacity, ensures that a uniform temperature distribution is achieved rapidly.

## CONCLUSION

CE alloys offer application solutions, which enhance product performance, reliability, increase in the functionality-to-weight ratio and are cost competitive. They lend themselves to manufacture by standard machining and plating procedures. The favorable combination of processing capabilities of these alloys present flexible opportunities for the manufacture of diverse products. They are available in the form of plates and blocks, or machined and plated components, ready for manufacturing into different products. ■

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1. S. Weinshanker, et al., "High Performance, Lightweight, Hermetic AlSi Packages for Military, Aerospace and Space Applications," *2nd Advanced Technology Workshop on Military, Aerospace, Space and Homeland Security: Packaging Issues and Applications*, Baltimore, MD, 29 March 2004.

# RIGOROUS ANALYTICAL EXPRESSIONS FOR THE ELECTROMAGNETIC PARAMETERS OF RECTANGULAR COAXIAL COUPLERS WITH CIRCULAR AND SQUARE INNER CONDUCTORS

*This article presents a set of accurate closed-form formulas for the primary parameters (inductance [L] and capacitance [C] matrices) and the impedances ($Z_{oe}$, $Z_{oo}$) of the even- and odd-modes for rectangular coaxial couplers with circular and square inner conductors. The analytical expressions, deduced from rigorous analysis by the finite element method (FEM),[1,2] the method of moment (MoM)[3] and curves fitting techniques, can be easily implemented in CAD simulation tools to design components for wireless communication. This study presents accurate and suitable general expressions for all rectangular coaxial couplers with a wide range of cut depth 'd' and an outer to inner conductor ratio between 1.4 and 10.*

The electrical properties of a loss-less coupler, using TEM mode coupled lines, can be described in terms of even- ($Z_{oe}$) and odd- ($Z_{oo}$) mode impedances and its primary parameters [L] and [C] matrices[2]

where

$$[L]=\begin{bmatrix} L_o & M \\ M & L_o \end{bmatrix} \text{and} [C]=\begin{bmatrix} C_o & -\gamma \\ -\gamma & C_o \end{bmatrix} \quad (1)$$

$L_o$ and $C_o$ are the proper inductance and capacitance of the isolated lines, respectively. M and $\gamma$ are the mutual inductance and coupling capacitance of the coupled lines, respectively.

Various numerical techniques can be used to determine the accurate electromagnetic parameters of the coupled lines. However, they

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are too time-consuming for direct use in circuit design. Closed-form analytical models are highly desirable in circuit design. This article presents a set of rigorous expressions for the characteristic impedances, elements of the inductance and capacitance matrices for rectangular coaxial couplers with circular and square inner conductors having an outer to inner conductor ratio between 1.4 and 10 and a parameter *u*, related to the cut depth d, varying between 0 and 0.99. These expressions are deduced from analysis results of the structures by the finite element method (FEM) and the method of moment (MoM).[1–3]

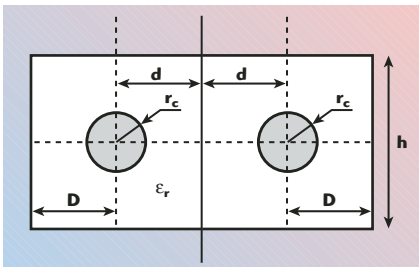


*Fig. 1 Cross-section of the rectangular coaxial coupler with circular inner conductors.*

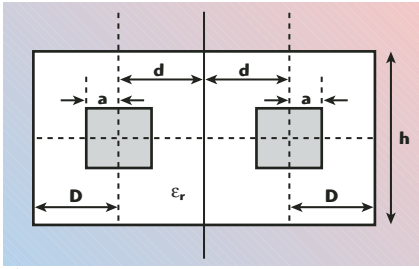


*Fig. 2 Cross-section of the rectangular coaxial coupler with square inner conductors.*

## RECTANGULAR COAXIAL COUPLERS WITH CIRCULAR AND SQUARE INNER CONDUCTORS

The cross-sections of rectangular coaxial couplers with circular and square inner conductors are shown in ***Figures 1*** and **2**, respectively. Each coaxial line is assumed to be lossless, with an inner conductor of radius $r_c$ or side 2a, and an outer rectangular conductor of height h and width W = 2D. The coaxial lines are filled with a material with a dielectric constant $\varepsilon_\rho$. A portion of each cable is cut out and two of these cut cables are joined to form the coupled line. The cut depth is shown as d on the cross-section and

$$u = \frac{\cos^{-1}\left(\frac{d}{D}\right)}{\cos^{-1}\left(\frac{1}{r}\right)} \qquad (2)$$

where

$r = \frac{D}{r_c}$ for the coupler with circular inner conductors

$r = \frac{D}{a}$ for the coupler with square inner conductors

## RECTANGULAR COAXIAL COUPLERS WITH CIRCULAR INNER CONDUCTORS

### Numerical Results

The numerical results for the electromagnetic parameters ($Z_{oe}$, $Z_{oo}$, [L] and [C]) of the rectangular coaxial couplers with circular inner conductors are shown in ***Figures 3*** to ***8***. The impedance results obtained demonstrate the excellent coherence between the FEM and MoM methods.

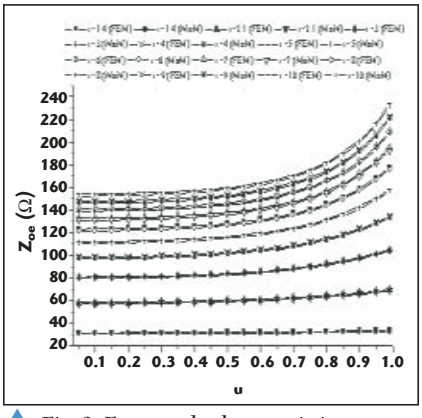


*Fig. 3 Even-mode characteristic impedance as a function of cut depth (u) with outer to inner conductor ratio as a parameter.*

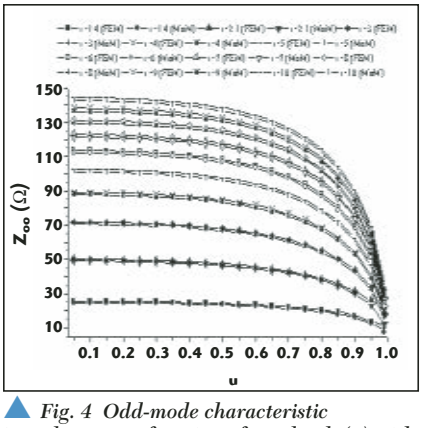


*Fig. 4 Odd-mode characteristic impedance as a function of cut depth (u) with outer to inner conductor ratio as a parameter.*

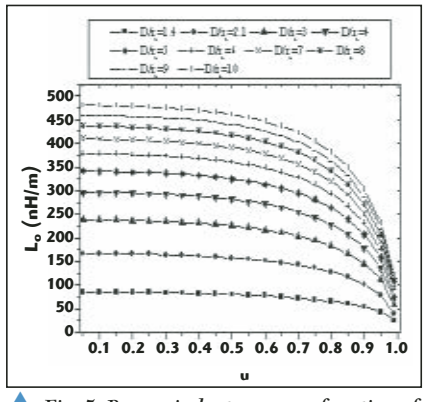


*Fig. 5 Proper inductance as a function of cut depth (u) with outer to inner conductor ratio as a parameter.*

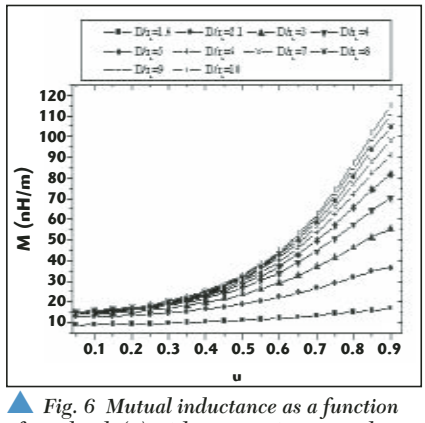


*Fig. 6 Mutual inductance as a function of cut depth (u) with outer to inner conductor ratio as a parameter.*

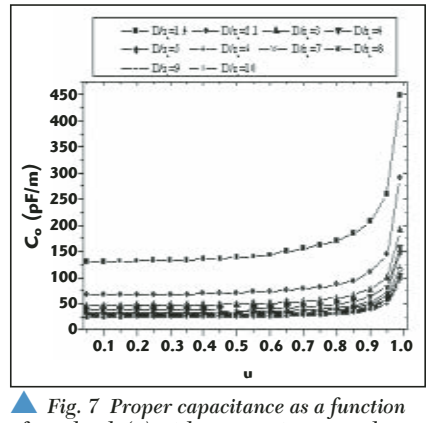


*Fig. 7 Proper capacitance as a function of cut depth (u) with outer to inner conductor ratio as a parameter.*

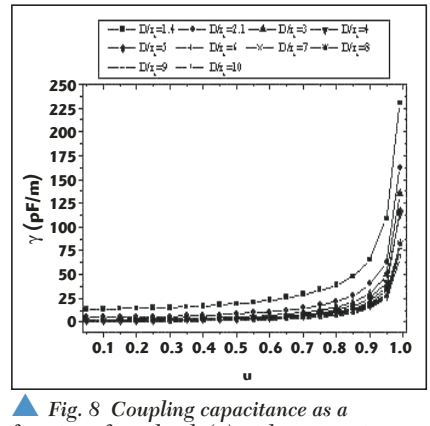


*Fig. 8 Coupling capacitance as a function of cut depth (u) with outer to inner conductor ratio as a parameter.*

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## DERIVATION OF ANALYTICAL EXPRESSIONS

### Characteristic Impedances

Equation 3 expresses the even-mode characteristic impedance ($Z_{oe}$) of the coupled lines

$$Z_{oe} = Z_o + a_1u + a_2u^2 + a_3u^3 \ (\Omega) \quad (3)$$

where

$$Z_o = -42.875 + 68.655r - 12.193r^2 + 1.115r^3 - 0.039r^4$$

$$a_1 = 5.419 - 9.348r + 4.678r^2 - 0.469r^3 + 0.016r^4$$

$$a_2 = -25.319 + 40.886r - 18.12r^2 + 1.861r^3 - 0.066r^4$$

$$a_3 = 0.855 - 16.724r + 13.781r^2 - 1.551r^3 + 0.058r^4$$

$$r = \frac{D}{r_c}$$

Equation 4 gives the odd-mode characteristic impedance ($Z_{oo}$) of the coupled line

$$Z_{oo} = \frac{a_1 - a_2}{1 + \exp\left(\frac{u - u_o}{du}\right)} + a_2 \ (\Omega) \quad (4)$$

where

$$a_1 = -27.87 + 50.10r - 7.19r^2 + 0.57r^3 - 0.01r^4$$

$$du = 0.33 - 0.09r + 0.02r^2 - 0.002r^3$$

For $1.4 \le r \le 7$

$$a_2 = 1617293 - 15272.83r + 4633.24r^2 - 629.51r^3 + 31.37r^4$$

$$u_o = 1.703$$

For $7 < r \le 10$

$$a_2 = -670.37 - 64r$$

$$u_o = 1.436$$

$$r = \frac{D}{r_c}$$

### Inductance Per Unit Length Matrix

Equations 5 and 6 give the proper and the mutual inductances of the rectangular coaxial coupler with circular inner conductors, respectively

$$L_o = \frac{a_1 - a_2}{1 + \exp\left(\frac{u - u_o}{du}\right)} + a_2 \left(\frac{nH}{m}\right) \quad (5)$$

$$a_1 = -135.31 + 199.68r - 33.05r^2 + 2.92r^3 - 0.1r^4$$

$$a_2 = 404.51 - 553.23r + 117.66r^2 - 12.37r^3 + 0.47r^4$$

$$u_0 = 1.21 - 0.03r + 6.6 \bullet 10^{-3}r^2 - 6.17 \bullet 10^{-4}r^3 + 2.19 \bullet 10^{-5}r^4$$

$$du = 0.19 - 0.04r + 0.012r^2 - 13.9 \bullet 10^{-4}r^3 + 5.5 \bullet 10^{-5}r^4$$

$$M = \frac{a_1 - a_2}{1 + \exp\left(\frac{u - u_o}{du}\right)} + a_2 \left(\frac{nH}{m}\right) \quad (6)$$

$$a_1 = -10.2 + 21.76r - 7.77r^2 + 1.33r^3 - 3 \bullet 10^{-3}r^5$$

$$a_2 = -3.96 + 7.88r + 16.08r^2 - 4.1r^3 + 0.41r^4 - 1.51 \bullet 10^{-2}r^5$$

$$u_0 = 0.43 + 0.33r - 0.1r^2 + 1.7 \bullet 10^{-2}r^3 - 1.3 \bullet 10^{-3}r^4 + 3.89 \bullet 10^{-5}r^5$$

$$du = 0.71 - 0.54r + 0.2r^2 - 0.03r^3 + 3.1 \bullet 10^{-3}r^4 - 1.01 \bullet 10^{-4}r^5$$

### Capacitance Per Unit Length Matrix

Equations 7 and 8 give the proper and coupling capacitances of the rectangular coaxial coupler with circular inner conductors, respectively

$$C_o = \frac{a_1 - a_2}{1 + \exp\left(\frac{u - u_o}{du}\right)} + a_2 \left(\frac{pF}{m}\right) \quad (7)$$

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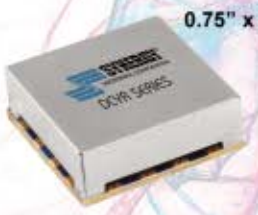


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| DCYR3097-5 | 300 - 970 | 0.5 to 28 | +5 | < 65 | -132 dBc/Hz | -40 to +85 | 0.75 x 0.75 |
| DCYR100200-12* | 1000 - 2000 | 0 to 28 | +12 | 35 | -128 dBc/Hz | -40 to +85 | 0.75 x 0.75 |
| DCYR120200-12* | 1200 - 2000 | 0.5 to 28 | +12 | 35 | -125 dBc/Hz | -40 to +85 | 0.75 x 0.75 |
| DCYR300600-5* | 3000 - 6000 | 0 to 25 | +5 | 45 | -105 dBc/Hz | -20 to +70 | 0.75 x 0.75 |
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| DCYS200400-5* | 2000 - 4000 | 0 to +15 | +5 | 45 | -113 dBc/Hz | -20 to +70 | 0.5 x 0.5 |
| DCYS250500-5* | 2500 - 5000 | 0 to +20 | +5 | 45 | -105 dBc/Hz | -20 to +70 | 0.5 x 0.5 |
| DCYS300600-5* | 3000 - 6000 | 0 to +25 | +5 | 45 | -102 dBc/Hz | -20 to +70 | 0.5 x 0.5 |

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**TABLE I**

**COMPARISON BETWEEN ANALYTICAL AND NUMERICAL RESULTS FOR RECTANGULAR COUPLED LINES WITH CYLINDRICAL INNER CONDUCTORS**

| Electromagnetic Parameters | FEM Results | Analytical Results | Errors (%) | Electromagnetic Parameters | FEM Results | Analytical Results | Errors (%) |
|---|---|---|---|---|---|---|---|
| (a) r = 3.041, u = 0.45, $\varepsilon_r$ = 2.03 | | | | (b) r = 5.271, u = 0.85, $\varepsilon_r$ = 2.03 | | | |
| $Z_{oe}$ (Ω) | 59.013 | 59.006 | 0.85 | $Z_{oe}$ (Ω) | 98.97 | 99.717 | 0.74 |
| $Z_{oo}$ (Ω) | 48.905 | 48.319 | 1.21 | $Z_{oo}$ (Ω) | 52.329 | 52.128 | 0.38 |
| $L_o$ (nH/m) | 236.967 | 233.761 | 1.37 | $L_o$ (nH/m) | 248.673 | 250.127 | 0.58 |
| M (nH/m) | 21.045 | 20.698 | 1.65 | M (nH/m) | 75.430 | 76.127 | 0.98 |
| $C_o$ (pF/m) | 98.51 | 97.148 | 1.40 | $C_o$ (pF/m) | 79.127 | 78.172 | 1.17 |
| γ (pF/m) | 12.301 | 12.176 | 1.02 | γ (pF/m) | 18.445 | 18.197 | 1.36 |

$$a_1 = 636.152 - 654.732r + 297.01r^2 - 70.008r^3 + 8.953r^4 - 0.588r^5 + 0.015r^6$$

$$a_2 = 4108 - 2787.528r + 886.261r^2 - 140.887r^3 + 10.924r^4 - 0.328r^5$$

$$u_0 = 1.077 - 0.021r + 5.14\bullet10^{-3}r^2 - 5.301\bullet10^{-4}r^3 + 1.928\bullet10^{-5}r^4$$

$$du = 0.063 - 0.015r + 3.81\bullet10^{-3}r^2 - 3.931\bullet10^{-4}r^3 + 1.433\bullet10^{-5}r^4$$

$$\gamma = \frac{a_1 - a_2}{1 + \exp\left(\frac{u - u_o}{du}\right)} + a_2 \left(\frac{pF}{m}\right) \quad (8)$$

$$a_1 = 96.131 - 100.263r + 45.388r^2 - 10.665r^3 + 1.354r^3 + 1.354r^4 - 0.088r^5 + 2.32\bullet10^{-3}r^6$$

$$a_2 = 3695.365 - 3693.468r + 1798.763r^2 - 452.424r^3 + 60.805r^4 - 4.146r^5 + 0.112r^6$$

For $r \le 5$

$$u_0 = 1.203 - 0.186r + 0.076r^2 - 0.012r^3 + 7.133\bullet10^{-4}r^4$$

$$du = 0.105 - 0.063r + 0.02r^2 - 2.29\bullet10^{-3}r^3 + 3.221\bullet10^{-5}r^4$$

For $r > 5$

$$u_0 = -0.421 + 0.769r - 0.146r^2 - 3.541\bullet10^{-4}r^4$$

$$du = -047 + 0.272r - 0.052r^2 + 4.23\bullet10^{-3}r^3 - 1.237\bullet10^{-4}r^4$$

***Table 1*** shows a comparison between the analytical and numerical results. The relative errors between the numerical and analytical results are less than 2 percent over a wide range, indicating the good accuracy of the closed-form expressions for rectangular coaxial couplers with circular inner conductors.

## RECTANGULAR COAXIAL COUPLERS WITH SQUARE INNER CONDUCTORS

### Numerical Results

***Figures 9*** and ***10*** show the characteristic impedances of the rectan-

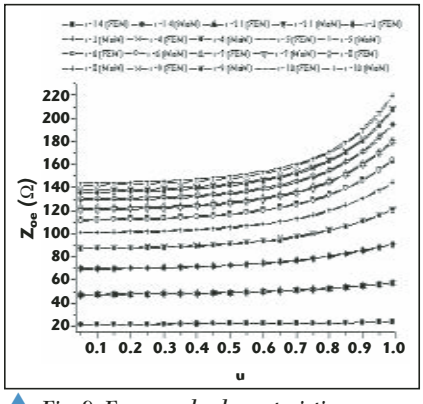


*Fig. 9 Even-mode characteristic impedance as a function of cut depth (u) with outer to inner conductor ratio as a parameter.*

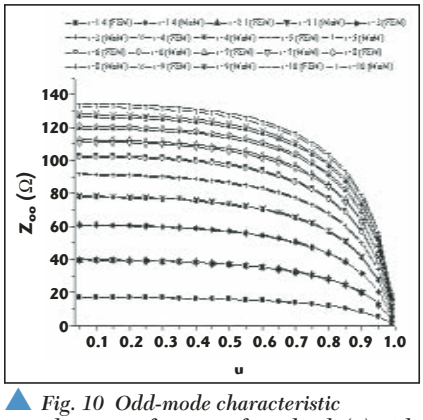


*Fig. 10 Odd-mode characteristic impedance as a function of cut depth (u) with outer to inner conductor ratio as a parameter.*

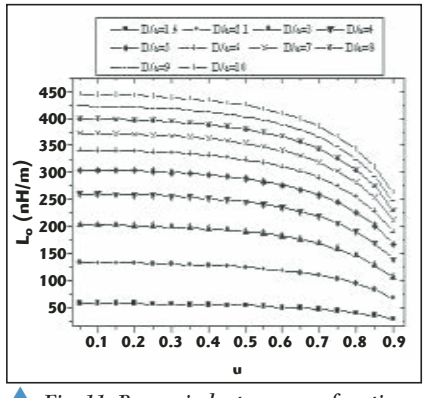


*Fig. 11 Proper inductance as a function of cut depth (u) with outer to inner conductor ratio as a parameter.*

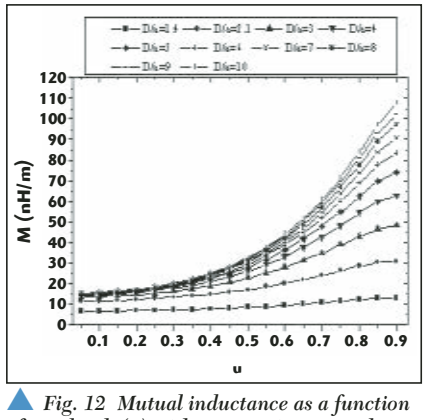


*Fig. 12 Mutual inductance as a function of cut depth (u) with outer to inner conductor ratio as a parameter.*

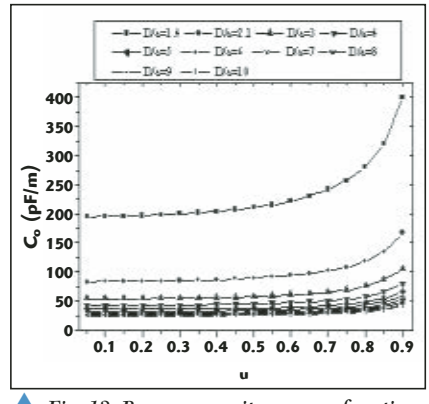


*Fig. 13 Proper capacitance as a function of cut depth (u) with outer to inner conductor ratio as a parameter.*

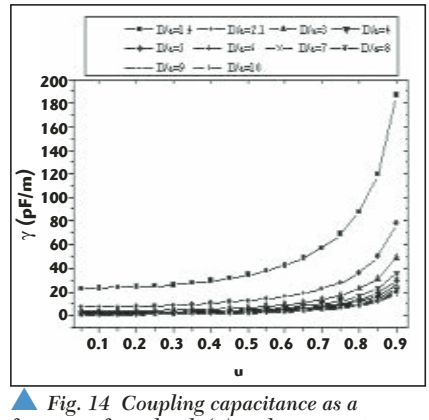


*Fig. 14 Coupling capacitance as a function of cut depth (u) with outer to inner conductor ratio as a parameter.*

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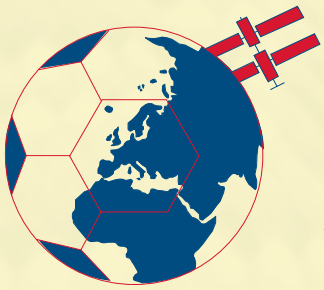

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gular coaxial couplers with square inner conductors, calculated using the coherent methods (FEM and MoM).

The numerical results for the elements of the [L] and [C] matrices, for different values of outer to inner conductors ratios, are shown in ***Figures 11*** to ***14***.

## DERIVATION OF ANALYTICAL EXPRESSIONS

### Characteristic Impedances

For this type of coupler, the even-mode characteristic impedance ($Z_{oe}$) can be expressed by

$$Z_{oe} = Z_o + a_1u + a_2u^2 + a_3u^3 \ (\Omega) \quad (9)$$

where

$$Z_o = -52.252 + 69.345r - 12.711r^2 + 1.203r^3 - 0.043r^4$$
$$a_1 = 3.794 - 6.272r + 3.107r^2 - 0.284r^3 + 0.008r^4$$
$$a_2 = -22.907 + 33.252r - 13.71r^2 + 1.331r^3 - 0.043r^4$$
$$a_3 = 2.671 - 14.292r + 11.112r^2 - 1.207r^3 + 0.042r^4$$

$$r = \frac{D}{a}$$

Equation 10 gives the odd-mode characteristic impedance ($Z_{oo}$)

$$Z_{oo} = \frac{a_1 - a_2}{1 + \exp\left(\frac{u - u_o}{du}\right)} + a_2 \ (\Omega) \quad (10)$$

$$a_1 = -45.588 + 55.932r - 8.864r^2 + 0.765r^3 - 0.025r^4$$
$$du = 0.212 - 0.022r + 0.008r^2 - 0.001r^3 + 1.753\bullet10^{-4}r^4 - 6.4\bullet10^{-6}r^5$$

For $1.4 \le r \le 5$

$$a_2 = 3982.549 - 5536.278r + 1970.358r^2 - 367.354r^3 + 25.947r^4$$
$$u_0 = 1.723 + 0.123r - 0.088r^2 + 0.02r^3 - 1.61\bullet10^{-3}r^4$$

For $5 < r \le 10$

$$a_2 = -552.402 - 65.032r$$
$$u_0 = 1.439 + 0.018r - 0.008r^2 + 1.08\bullet10^{-3}r^3 - 4.166\bullet10^{-5}r^4$$

$$r = \frac{D}{a}$$

### Inductance Per Unit Length Matrix

Equations 11 and 12 give the proper and the mutual inductances of the rectangular coaxial coupler with square inner conductors

$$L_o = \frac{a_1 - a_2}{1 + \exp\left(\frac{u - u_o}{du}\right)} + a_2 \left(\frac{nH}{m}\right) \quad (11)$$

$$a_1 = -152.885 + 187.924r - 30.058r^2 + 2.611r^3 - 0.088r^4$$
$$a_2 = 2988.219 - 2925.588r - 268.68r^2 + 616.533r^3 - 172.104r^4 + 18.054r^5 - 0.654r^6$$
$$du = 0.221 - 0.015r + 2.3\bullet10^{-3}r^2 - 1.4\bullet10^{-4}r^3 + 2.356\bullet10^{-6}r^4$$

For $r \le 5$

$$u_0 = 1.576 - 0.054r + 5.02\bullet10^{-3}r^2$$

For $r > 5$

$$u_0 = 2.381 - 0.281r + 0.032r^2 - 1.28\bullet10^{-3}r^3$$

$$M = \frac{a_1 - a_2}{1 + \exp\left(\frac{u - u_o}{du}\right)} + a_2 \left(\frac{nH}{m}\right) \quad (12)$$

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**TABLE II**

**COMPARISON BETWEEN ANALYTICAL AND NUMERICAL RESULTS FOR RECTANGULAR COUPLED LINES WITH SQUARE INNER CONDUCTORS**

| Electromagnetic Parameters | FEM Results | Analytical Results | Errors (%) | Electromagnetic Parameters | FEM Results | Analytical Results | Errors (%) |
|---|---|---|---|---|---|---|---|
| (a) r = 3.59, u = 0.45, $\varepsilon_r$ = 2.03 | | | | (b) r = 6.236, u = 0.56, $\varepsilon_r$ = 2.03 | | | |
| $Z_{oe}$ (Ω) | 59.69 | 59.42 | 0.45 | $Z_{oe}$ (Ω) | 85.39 | 85.14 | 0.29 |
| $Z_{oo}$ (Ω) | 48.75 | 48.61 | 0.29 | $Z_{oo}$ (Ω) | 69.40 | 69.68 | 0.40 |
| $L_o$ (nH/m) | 229.1 | 230.845 | 0.76 | $L_o$ (nH/m) | 302.41 | 301.02 | 0.46 |
| M (nH/m) | 22.45 | 22.361 | 0.39 | M (nH/m) | 35.81 | 35.31 | 1.41 |
| $C_o$ (pF/m) | 98.88 | 98.066 | 0.82 | $C_o$ (pF/m) | 62.65 | 62.26 | 0.62 |
| γ (pF/m) | 6.73 | 6.675 | 0.89 | γ (pF/m) | 6.59 | 6.517 | 1.22 |

$$a_1 = 18.516 + 29.954r - 11.049r^2 + 1.992r^3 - 0.174r^4 + 5.91\bullet10^{-3}r^5$$
$$a_2 = -36.5 + 41.429r - 3.26r^2 + 0.138r^3$$
$$u_0 = 0.664 + 0.011r + 6.35\bullet10^{-3}r^2 - 1.01\bullet10^{-3}r^3 + 4.65\bullet10^{-5}r^4$$
$$du = 0.124 + 0.051r - 0.023r^2 + 5.22\bullet10^{-3}r^3 - 5.857\bullet10^{-4}r^4 + 3.165\bullet10^{-5}r^5 - 6.334\bullet10^{-7}r^6$$

### Capacitance Per Unit Length Matrix

Finally, Equations 13 and 14 give the proper and the coupling capacitance of the rectangular coaxial coupler with square inner conductors

$$C_o = \frac{a_1 - a_2}{1 + \exp\left(\frac{u - u_o}{du}\right)} + a_2 \left(\frac{pF}{m}\right) \quad (13)$$

$$a_1 = 1077.527 - 1180.78r + 548.531r^2 - 131.222r^3 + 16.959r^4 - 1.124r^5 + 0.029r^6$$
$$a_2 = 21605.617 - 23921.884r + 11115.242r^2 - 2660.873r^3 + 344.19r^4 - 22.835r^5 + 0.608r^6$$
$$u_0 = 1.263 - 0.014r + 2.05\bullet10^{-3}r^2 - 1.204\bullet10^{-4}r^3 + 2.309\bullet10^{-6}r^4$$
$$du = 0.123 - 4.53\bullet10^{-3}r + 2.56\bullet10^{-3}r^2 - 7.527\bullet10^{-4}r^3 + 11.819\bullet10^{-5}r^4 - 9.247\bullet10^{-6}r^5 + 2.829\bullet10^{-7}r^6$$

$$\gamma = \frac{a_1 - a_2}{1 + \exp\left(\frac{u - u_o}{du}\right)} + a_2 \left(\frac{pF}{m}\right) \quad (14)$$

$$a_1 = 116.203 - 106.648r + 38.355r^2 - 6.584r^3 + 0.539r^4 - 0.016r^5$$
$$a_2 = 12357.589 - 10845.464r + 3847.1r^2 - 656.096r^3 + 53.544r^4 - 1.677r^5$$
$$du = 0.089 + 0.025r - 7.76\bullet10^{-3}r^2 + 11.8\bullet10^{-4}r^3 - 8.766\bullet10^{-5}r^4 + 2.538\bullet10^{-6}r^5$$
$$u_0 = 1.181 + 0.065r - 0.024r^2 + 4.18\bullet10^{-3}r^3 - 3.303\bullet10^{-4}r^4 + 1\bullet10^{-5}r^5$$

A comparison between the analytical and the numerical results is given in ***Table 2***, showing the good accuracy of the closed-form expressions for the rectangular coaxial couplers with square inner conductors.

## CONCLUSION

This article presents a set of accurate, closed-form formulas for the primary parameters (inductance [L] and capacitance [C] matrices) and the impedances ($Z_{oe}$, $Z_{oo}$) of the even- and odd-modes for rectangular coaxial couplers with circular and square inner conductors. These expressions, deduced from analysis results by the finite element method and the method of moment, are valid in a wide range of outer to inner conductor ratios. ■

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**Nasreddine Benahmed** *received his DSc degree from the University of Tlemcen, Algeria, in 2002. He has been a professor of communication systems since 2003. His current interests include RF and microwave transmission lines.*

**Salima Seghier** *is working on her MS degree in electronics, specializing in microwave and telecommunication systems at the University of Saida, Algeria. She is presently working as a communications engineer.*

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| iT2008K | 0.01 to 26.5 | 10 | 1 | 29 (10 GHz)<br>14.5 (26.5 GHz) | Package and Die |
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# A DUAL-BAND BRANCH-LINE COUPLER USING QUASI-COMPOSITE RIGHT/LEFT-HANDED TRANSMISSION LINES

*A quasi-RH/LH dual-band 3 dB branch-line coupler (BLC) constructed in microstrip form is proposed. The designed BLC circuit replaces the conventional chip inductors in the coupler arms with microstrip stubs for easier circuit integration and lower fabrication cost, while providing favorable dual-band operation. The newly designed BLC is implemented on an RT/Duroid 6010 substrate with all microstripline sections in the coupler arms meandered to reduce the circuit size. With an amplitude-difference less than 1 dB and a phase-difference of between 80° and 100° required between the two output arms, the designed BLC exhibits dual operating bands having fractional bandwidths of 17.3 and 8.4 percent for the first and second band, respectively, which are wider than those of many dual-band 3 dB BLCs reported in the literature.*

Branch-line couplers (BLC) are widely used as 90° signal dividers in microwave and millimeter-wave circuits. A BLC can provide two quadrature-phased signals from a single local oscillator for use in image rejection mixers.[1] It can be used as part of the feeding network for antennas to produce circularly polarized waves.[2] In addition, BLCs are often implemented in balanced amplifiers[3] and mixers to achieve good return loss. Conventional BLCs are usually constructed using quarter-wavelength ($\lambda/4$) right-handed transmission lines (RH TL). They only operate at a fundamental frequency and its odd harmonics. Such BLCs are usually large in size, and their applications to wideband and multiband systems are thus limited. Techniques for improving BLC performance and circuit compactness were developed and reported in the literature during the past few years. C.T. Lin, et al. described a CPW BLC[4] designed using bent structures to reduce the size of the normal quarter-wavelength arms. In addition, compensated networks are added at each of the four ports to achieve a wider bandwidth. Cheng and Wang[5] have shown a novel ap-

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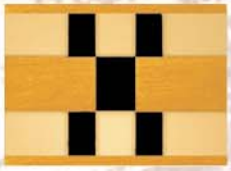

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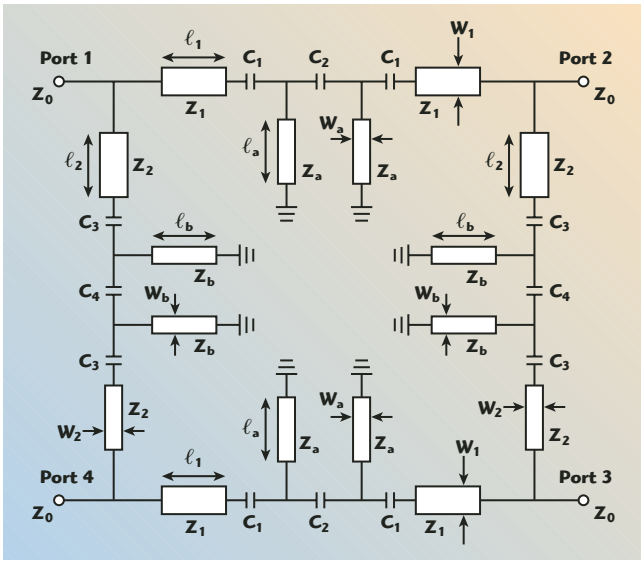


*Fig. 1 Topology of the proposed branch-line coupler.*

proach where each arm of the BLC is replaced with an equivalent circuit, consisting of a shorter high impedance TL section and two shunt elements, to reduce the circuit size and increase the bandwidth. Park and Lee proposed a new BLC geometry[6] with an additional pair of cross coupling branches to provide dual-band operation and more design freedom.

In recent years, dual-band BLCs implemented using composite right/left-handed transmission lines (CRLH TL) have been gaining favor. L.H. Lin, et al. described a dual-band BLC[7] that employs the phase-lead property of the LH TL to compensate for the phase lag of the RH TL in the circuit design. In this way, the two operating bands of the BLC can be designed with their center frequencies having a ratio other than 1:3; the second operating band needs not be the third harmonic. This feature is shown to be useful in modern communication systems with dual-band operation, since the two operating frequencies are separated by a factor less than three in current wireless standards.

In this article, a newly designed quasi-CRLH TL is used to implement the dual-band BLC. The chip inductors in the LH TL, consisting of lumped elements, are replaced with shorted transmission-line (STL) stubs for easier circuit integration and lower fabrication cost. The STL stubs can be made equivalent to the inductances needed in the construction of the LH TL in the first operating band. This will ensure that each arm of the BLC behaves as a CRLH TL only in the first band, but not in the second band (thus the name quasi-CRLH TL). This is because in the second band the STL stubs may not correspond to the same required inductances. Nevertheless, through circuit analysis and numerical optimization, it is found that if the inductances in the CRLH TL are replaced with capacitances of appropriate values, the entire BLC can still preserve a 3 dB coupling operation in the second band. Careful design of the STLs will make them exhibit the desired inductances in the first band and capacitances in the second band, thus achieving a 3 dB dual-band operation. The BLC arms are meandered to reduce the circuit size. The designed BLC possesses two operating bands with the first one centered at 946 MHz and the second one at 1796 MHz. With a less than 1 dB amplitude-difference requirement and a phase-difference constraint between 80° and 100°, this BLC exhibits dual operating bands having fractional bandwidths of 17.3 and 8.4 percent, respectively, which are wider than those of many dual-band 3 dB BLCs that have been reported in the literature. Compared with the BLC mentioned previously,[7] the proposed BLC not only provides a better performance dual-band operation but also features easy fabrication and a relatively compact circuit size.

## DUAL-BAND BRANCH-LINE COUPLER DESIGN

***Figure 1*** shows the circuit topology for the dual-band 3 dB BLC considered. For convenience, the circuit elements connecting ports 1 and 2 (and also ports 3 and 4) are referred to as being located in the series arms; those connecting ports 1 and 4 (and also ports 2 and 3) in the parallel arms. All four microstripline sections labeled with characteristic impedances $Z_1$ ($Z_2$) are of the same lengths $\ell_1$ ($\ell_2$) and widths $w_1$ ($w_2$). Similarly, those labeled with $Z_a$ ($Z_b$) have the same lengths $\ell_a$ ($\ell_b$) and widths $w_a$ ($w_b$). The capacitances $C_1$ to $C_4$ can be implemented using chip capacitors. If the shunt, shorted transmission-line (STL) stubs on the series arms (parallel arms) are replaced by inductances $L_a$ ($L_b$), then this structure becomes the RH/LH dual-band BLC mentioned previously[7]. It is known that a conventional 3 dB BLC consisting of λ/4 RH TLs operates at a fundamental center frequency and its odd multiple harmonics, provided that the effective dielectric constant and the characteristic impedance of the TL sections therein are insensitive to frequency variations. Nevertheless, the CRLH BLC can be designed for dual-band operation with its first and second operating frequencies (denoted by $f_1$ and $f_2$, respectively) having a ratio other than 1:3. For the circuit design of the CRLH BLC, the procedure outlined by Lin, et al.[7] can be employed to find the appropriate values of $L_a$, $L_b$ and $C_1$ to $C_4$. In this article, to ease the circuit fabrication process, $L_a$ and $L_b$ are replaced with STL stubs, such that the input impedances of these two stubs are equal to those of $L_a$ and $L_b$ at $f_1$. Hence, the circuit elements (including the two STL stubs and the three chip capacitors) between the two microstripline sections in the same arm behave as an LH transmission line at $f_1$.[7] However, the CRLH 3 dB coupling operation is not guaranteed at $f_2$, since these STL stubs may not exhibit input impedances corresponding to those of $L_a$ and $L_b$ at that operating frequency. The proposed BLC is thus only a quasi-CRLH one. Nevertheless, through extensive numerical simulation, it was found that the 3 dB coupling operation at $f_2$ can be achieved if $L_a$ and $L_b$ are replaced with some appropriate capacitances $C_a$ and $C_b$, respectively. These capacitance values can be found by performing circuit analysis and numerical optimization. The scattering parameters $S_{21}$ and $S_{31}$ of the quasi-CRLH BLC with $C_a$ ($C_b$) in shunt with the series (parallel) arms are shown in ***Appendix A***. Minimization routines, available in MATLAB,™ can be used to find appropriate $C_a$ and $C_b$ by minimizing the er-

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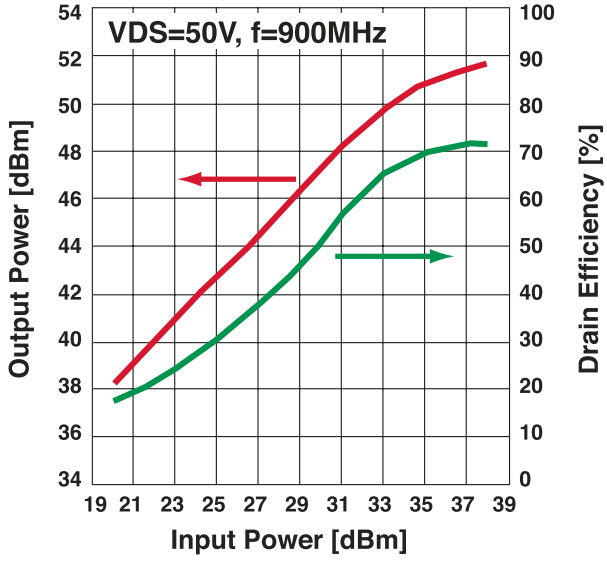


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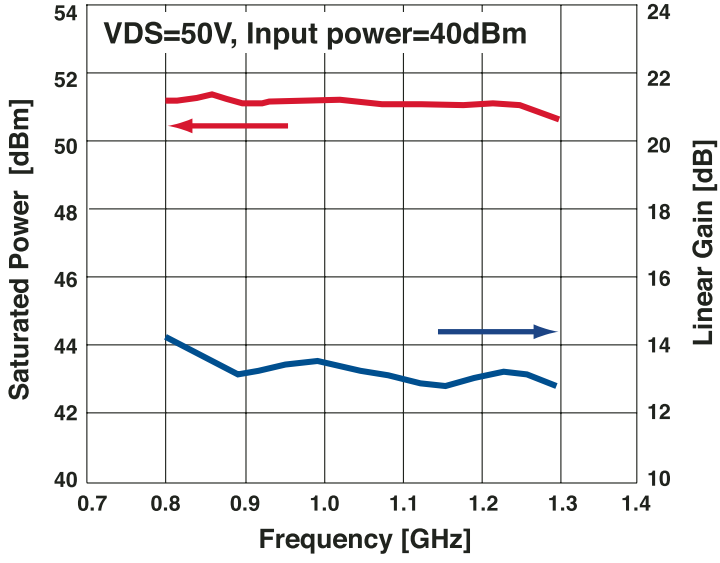


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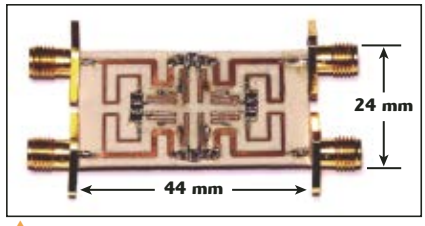


*Fig. 2 The implemented 3 dB quasi-CRLH BLC.*

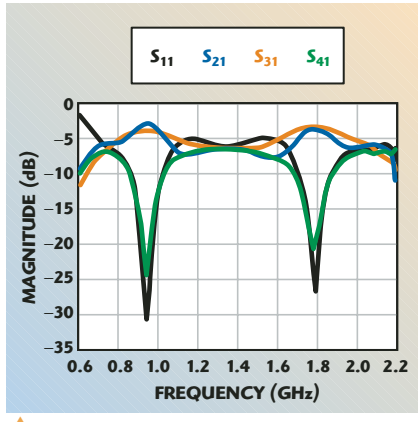


*Fig. 3 Simulated S-parameters of the BLC.*

rors $||S_{21}| - |S_{31}||$ and $||\angle S_{21} - \angle S_{31}| - \pi/2|$.

The described analysis shows that the BLC circuit with $L_a$ and $L_b$ provides a 3 dB coupling operation at $f_1$, whereas the one with $C_a$ and $C_b$ has a similar behavior at $f_2$. Thus, the STL stubs can be designed for the proposed BLC, such that they are equivalent to $L_a$ and $L_b$ at $f_1$ and to $C_a$ and $C_b$ at $f_2$ as

$$j2\pi f_1 L_p = jZ_p \tan\left[\theta_p(f_1)\right], \quad p = a, b \tag{1}$$

$$\frac{1}{j2\pi f_2 C_p} = jZ_p \tan\left[\theta_p(f_2)\right], \quad p = a, b \tag{2}$$

In Equations 1 and 2, the characteristic impedance ($Z_p$) of a microstripline as a function of h, $w_p$ and $\varepsilon_{rp}^{(eff)}$ can be found,[8] where h is the thickness of the substrate and $w_p$ and $\varepsilon_{rp}^{(eff)}$ are the width and effective dielectric constant of the microstripline, respectively. Here, the effective dielectric constant ($\varepsilon_{rp}^{(eff)}$) is a function of h, $w_p$ and $\varepsilon_r$ (the dielectric constant of the substrate).[8] Furthermore, the electric length ($\theta_p$) of the microstrip line can be expressed as

$$\theta_p(f) = \frac{2\pi f\sqrt{\varepsilon_{rp}^{(eff)}}}{C_0}\ell_p \tag{3}$$

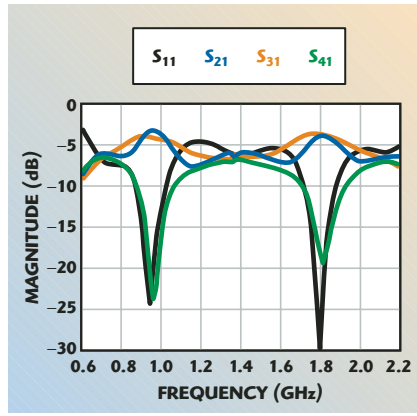


*Fig. 4 Measured S-parameters of the BLC.*

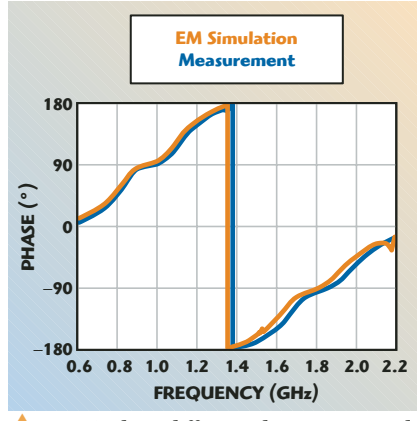


*Fig. 5 Phase difference between $S_{21}$ and $S_{31}$ of the BLC.*

Optimization routines in MATLAB can also be used to determine $\ell_p$ and $w_p$, p = a,b. The outlined approach was employed to design the proposed quasi-CRLH dual-band 3 dB BLC. The dual-band operation was demonstrated by replacing the chip inductors with appropriate STLs to ease the circuit fabrication process.

## CIRCUIT IMPLEMENTATION AND RESULTS

The circuit pattern was printed on a grounded RT/Duroid 6010 substrate 0.635 mm thick and with a dielectric constant of 10.2. The operating bands are designed to be centered at the frequencies of 925 and 1795 MHz. The 0805 chip capacitors are 21.2 mm. Following the described design procedure, the following circuit parameters were obtained: $\ell_1$ = 24 mm, $\ell_2$ = 25 mm, $Z_1$ = 35 Ω, $Z_2$ = 50 Ω, $w_a = w_b$ = 0.2 mm, $\ell_a$ = 20.5 mm, $\ell_b$ = 21.0 mm, $C_1$ = 36 pF, $C_2$ = 18 pF, $C_3$ = 28 pF and $C_4$ = 14 pF. The four capacitances, $C_1$, $C_2$, $C_3$ and $C_4$, are implemented by combining in parallel three

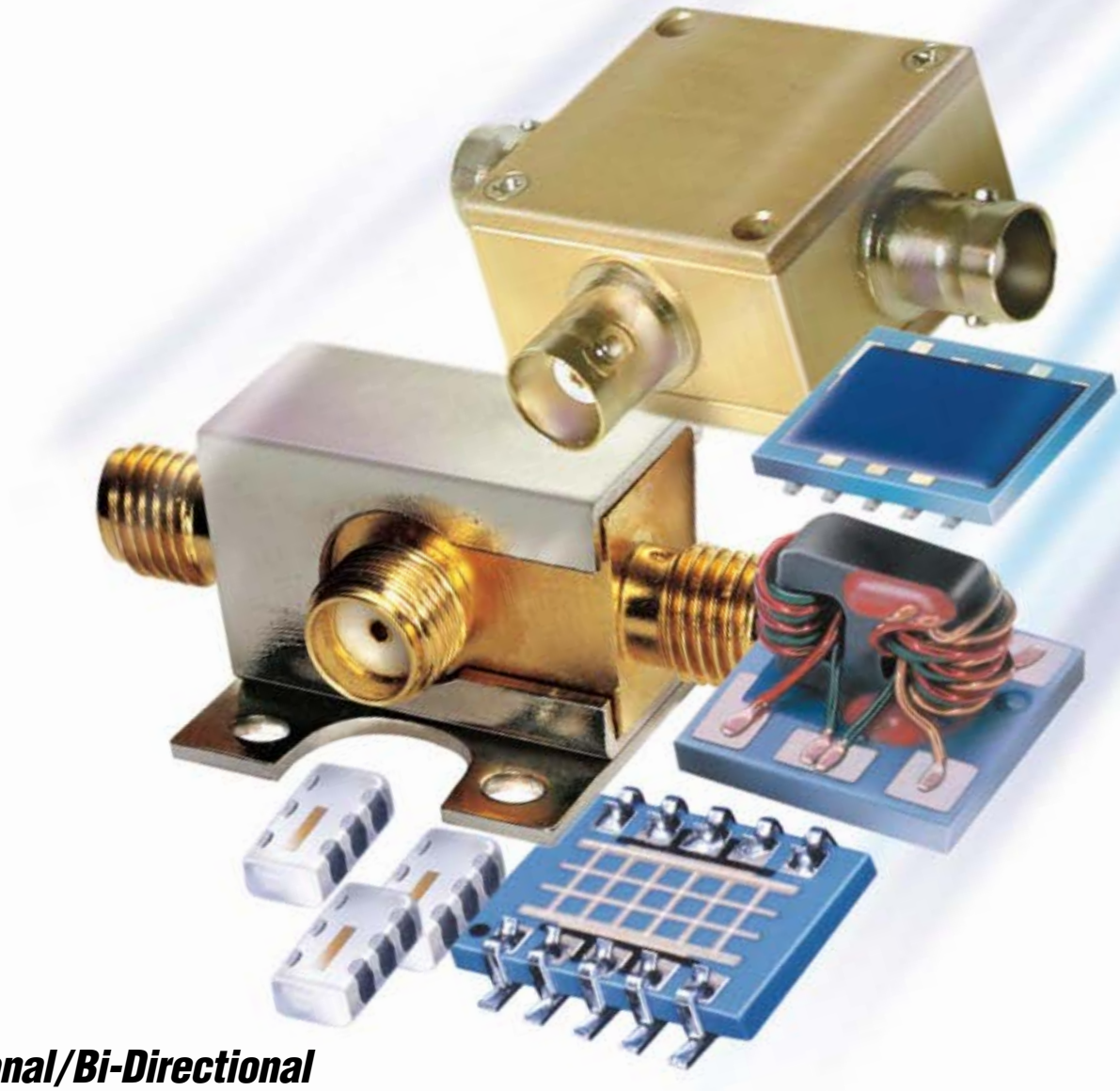

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**TABLE I**

**PERFORMANCE OF THE BLC IN THE FIRST OPERATING BAND**

| | Simulation | Measurement |
|---|---|---|
| Operating frequency ($f_1$) (MHz) | 945 | 946 |
| Return loss ($S_{11}$) (dB) | 30.4 | 24.2 |
| Isolation ($S_{41}$) (dB) | 24.37 | 20.1 |
| Output 1 ($S_{21}$) (dB) | –2.98 | –3.35 |
| Output 2 ($S_{31}$) (dB) | –3.87 | –4.07 |
| Amplitude imbalance (dB) | 0.89 | 0.72 |
| Phase difference | 89.72° | 89.7° |
| $BW_{(Type\ A)}$ | 311 MHz, 32.9% (730–1041 MHz) | 182 MHz, 19.2% (882–1064 MHz) |
| $BW_{(Type\ B)}$ | 159 MHz, 16.8% (882–1041 MHz) | 164 MHz, 17.3% (990–1054 MHz) |
| $BW_{(Type\ C)}$ | 78 MHz, 8.3% (905–983 MHz) | 60 MHz, 6.3% (924–984 MHz) |

**TABLE II**

**PERFORMANCE OF THE BLC IN THE SECOND OPERATING BAND**

| | Simulation | Measurement |
|---|---|---|
| Operating frequency ($f_2$) (MHz) | 1790 | 1796 |
| Return loss ($S_{11}$) (dB) | 26.7 | 29.5 |
| Isolation ($S_{41}$) (dB) | 20.1 | 18 |
| Output 1 ($S_{21}$) (dB) | –3.69 | –3.97 |
| Output 2 ($S_{31}$) (dB) | –3.31 | –3.67 |
| Amplitude imbalance (dB) | 0.38 | 0.3 |
| Phase difference | –91.37° | –94.2° |
| $BW_{(Type\ A)}$ | 118 MHz, 6.6% (1728–1846 MHz) | 156 MHz, 8.7% (1760–1916 MHz) |
| $BW_{(Type\ B)}$ | 118 MHz, 6.6% (1728–1846 MHz) | 150 MHz, 8.4% (1760–1910 MHz) |
| $BW_{(Type\ C)}$ | 76 MHz, 4.2% (1744–1820 MHz) | 66 MHz, 3.7% (1774–1840 MHz) |

12 pF capacitors, two 6 pF with two 3 pF capacitors, four 7pF capacitors and two 5 pF with two 2 pF capacitors, respectively. Combining the chip capacitors in parallel provides a better chance of reducing the total deviation of the capacitances from their target values. All the microstripline sections, including the ones with length $\ell_1$ in the series arms, the ones with length $\ell_2$ in the parallel arms, and the shunted STL stubs with lengths $\ell_a$ and $\ell_b$, are meandered to reduce the circuit size. ***Figure 2*** shows a photograph of the designed dual-band 3 dB BLC, whose circuit board measures only 44 × 24 mm and is less than one fifth of the size of the BLC reported previously.[7] ***Figures 3*** and ***4*** show the simulated and measured magnitudes of the S-parameters, respectively. The simulated results were obtained using the commercial software Ansoft High Frequency Structure Simulator (HFSS). ***Figure 5*** demonstrates the simulated and measured phase-difference between $S_{21}$ and $S_{31}$. ***Table 1*** summarizes all the important data for the first operating band and ***Table 2*** for the second operating band. The simulated and measured center frequencies are 945, 1790, 946 and 1796 MHz, respectively, which slightly deviates from the designed ones (925 and 1795 MHz). Three different types of bandwidths have been extracted from the simulated and measured data. The type A bandwidth is defined by the frequency range around the center frequency with $||S_{21}|\ (dB) - |S_{31}|\ (dB)| \le 1$ dB; the type B bandwidth, $||S_{21}|\ (dB) - |S_{31}|\ (dB)| \le 1$ dB and $|\angle S_{21} - \angle S_{31}| \le 10°$; the type C bandwidth, $|S_{11}| \le -15$ dB and $|S_{41}| \le -15$ dB, in addition to the criteria set in the type B bandwidth. Among these three bandwidth definitions, type C is the most stringent one, while type A is the loosest one. Hence, $BW_{(type\ A)} > BW_{(type\ B)} > BW_{(type\ C)}$ for both operating bands. Note that for the first band, the $BW_{(type\ C)}$ measured is less than the bandwidth published,[7] whereas $BW_{(type\ A)}$ and $BW_{(type\ B)}$ are larger. Also, for the second band, all three bandwidths (types A, B and C) measured are larger than the one published.[7] A first look at the measured S-parameters may suggest that the parameter $||S_{21}|\ (dB) - |S_{31}|\ (dB)|$ is larger than 1 dB. However, a careful scrutiny into the measured data reveals that near $f_1$ the largest value for $||S_{21}|\ (dB) - |S_{31}|\ (dB)|$ is 0.917 dB (at 972 MHz), a magnitude difference that still meets the type-A bandwidth criterion.

## CONCLUSION

A new dual-band 3 dB BLC has been proposed. The shunt STL stubs in the four arms of the BLC have been designed to replace the chip inductors, thus ensuring easier circuit integration and a lower fabrication cost. Although this circuit behaves as a RH/LH BLC only in the first operating band, its equal power-splitting and quadrature-phased properties at the two output ports can still be maintained in the second operating band. With all microstripline sections in the coupler arms meandered, the circuit size has been greatly reduced. The measured circuit performance has been found to compare favorably with that of many dual-band 3 dB BLCs seen in the literature. ■

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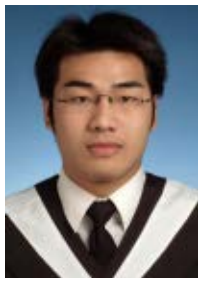

**He-Kai Jhuang** *received his BS degree in industrial education from the National Changhua University of Education, Changhua, Taiwan, in 2004. He is currently working toward his MS degree in electronic engineering at the same school. His current research interests include microstrip filter design and passive components for wireless communications.*

**Ching-Her Lee** *received his BS degree in electronic engineering and his MS degree in automatic control engineering from Feng-Chia University, Taichung, Taiwan, in 1977 and 1981, respectively. He received his PhD degree in electrical engineering from the University of Texas at Arlington in 1989. From 1981 to 1985, he was on the faculty of the Chin-Yih Institute of Technology, Taichung, Taiwan. In 1990, he joined the National Changhua University of Education, Changhua, Taiwan, where he is presently dean of the college of engineering. His research interests include planar microwave circuits and microstrip antennas.*

**Po-Min Hu** *received his BS degree in electrical engineering from Da-yeh University, Changhua county, Taiwan, in 2004. He is currently working toward his MS degree in telecommunications engineering at the same school. His research interests include the analysis and design of planar/microwave passive components.*

**Chung-I G. Hsu** *graduated from the National Taipei Institute of Technology, Taiwan, in 1980. He received his MS degree from the University of Mississippi and his PhD degree from Syracuse University in 1986 and 1991, respectively, both in electrical engineering. He spent the spring 1992 semester at the microwave and electromagnetics laboratory of Texas A&M University, doing research on the modeling of microstrip antennas. Since August 1992, he has been on the faculty of Da-Yeh University, where he is presently an associate professor of electrical engineering.*

## APPENDIX A

The scattering parameters $S_{21}$ and $S_{31}$ of the BLC structure shown in Figure 1 with the STL stubs replaced with $C_a$ and $C_b$ can be expressed as

$$S_{21} = \frac{Z_0}{\Delta}\left[(A_1+A_2)Z_0+(A_3+A_4)Z_0^2+2A_5\right] \quad \text{(A1)}$$

$$S_{31}=\frac{Z_0}{\Delta}\left[(A_1-A_2)Z_0+(A_3-A_4)Z_0^2\right] \quad \text{(A2)}$$

where

$$\Delta=\left(A_1Z_0+A_3Z_0^2+A_5\right)\left(A_2Z_0+A_4Z_0^2+A_5\right) \quad \text{(A3)}$$

$$A_1=2\cos^2\theta_1\left(K_1+\frac{K_2}{K_4}\right)-2\sin^2\theta_1\left(K_1+\frac{K_3Z_1^2}{K_4}\right)+2j\sin\theta_1\cos\theta_1\left(K_3Z_1+\frac{K_2}{Z_1}+\frac{2K_1Z_1}{K_4}\right) \quad \text{(A4)}$$

$$A_3=\cos^2\theta_1\left(K_3+\frac{2K_1}{K_4}+\frac{K_2}{K_4^2}\right)-\sin^2\theta_1\left(\frac{K_3Z_1^2}{K_4^2}+\frac{2K_1}{K_4}+\frac{K_2}{Z_1^2}\right)+2j\sin\theta_1\cos\theta_1\left(\frac{K_1}{Z_1}+\frac{K_2}{K_4Z_1}+\frac{K_3Z_1}{K_4}+\frac{K_1Z_1}{K_4^2}\right) \quad \text{(A5)}$$

$$A_5=\cos^2\theta_1K_2-\sin^2\theta_1K_3Z_1^2+2j\sin\theta_1\cos\theta_1K_1Z_1 \quad \text{(A6)}$$

In Equations A4 to A6,

$$K_1=1+\frac{2C_aC_2+C_aC_1+C_a^2}{C_1C_2} \quad \text{(A7)}$$

$$K_2=\frac{2(C_1C_2+C_aC_1+C_aC_2)+C_a^2+C_1^2}{j\omega C_1^2C_2} \quad \text{(A8)}$$

$$K_3=j\omega\left(2C_a+\frac{C_a^2}{C_2}\right) \quad \text{(A9)}$$

$$K_4=Z_2\frac{j(\omega C_3C_bZ_2\tan\theta_2-C_3-C_b)}{\omega C_3C_bZ_2+(C_3+C_b)\tan\theta_2} \quad \text{(A10)}$$

$$K_5=Z_2\frac{j\left[\omega C_3(2C_4+C_b)Z_2\tan\theta_2-C_3-2C_4-C_b\right]}{\omega C_3(2C_4+C_b)Z_2+(C_3+2C_4+C_b)\tan\theta_2} \quad \text{(A11)}$$

Moreover, the expressions of $A_2$ and $A_4$ can be obtained by substituting $K_4$ with $K_5$ in $A_1$ and $A_3$, respectively.

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# CHARACTERIZATION OF ULTRA-WIDEBAND BOW-TIE ANTENNAS FOR GROUND PENETRATING RADAR SYSTEMS

*In this article, two ultra-wideband (UWB) bow-tie antennas, designed for ground penetrating radar (GPR) applications, are characterized by both numerical analysis and experimental measurements. The geometry and the different materials of the feed and the radiating components of the antennas are fully taken into account in a detailed numerical three-dimensional model, based on the finite element method (FEM). The reliability of the FEM results is assessed by comparison with experimental measurements. The analysis is performed for a geometrical configuration of interest for actual GPR applications, where the antennas are located on the same side of a scattering object (reflection configuration). The validation measurements are conducted under laboratory conditions, both in absence of any scattering objects and in contact with a tuff masonry.*

In recent applications of telecommunications and remote sensing at radio, microwave and terahertz frequencies, the exploitation of ultra-wideband (UWB) antennas is growing steadily.[1] In subsurface prospecting, for example, they can provide higher imaging resolution and better target characterization.[2]

The design and analysis of such high performance antennas exhibit significant challenges.[3] In particular, in the case of GPR systems, typical requirements include not only a broad operating bandwidth for short "real" and "synthetic" pulse radiation, but also negligible interferences caused by scattering from undesired directions and small size to make the system portable.[2] Furthermore, since the antennas work in close proximity or in contact with the investigated structure, their input impedance and radiated field are affected, so that the properties of the background medium must be taken into account in designing and analyzing the antenna performance.[2,4] Finally, the mutual interaction between transmitting

FRANCESCO SOLDOVIERI
***IREA-CNR***
***Naples, Italy***
GIANCARLO PRISCO
AND ADRIANA BRANCACCIO
***Second University of Naples, Italy***
GIOVANNI LEONE
***University of Reggio Calabria, Italy***

and receiving antennas must be also considered. It is very difficult to measure the antenna properties (the radiated field, for example) under operative GPR conditions, characterized by an inhomogeneous variable scenario.[5] This gives rise to the need for a full-wave analysis of the antenna. An accurate modeling of the antenna is crucial for the exploitation of inverse scattering approaches to the GPR prospecting, since the accurate knowledge of the incident field (that is the field impinging on the investigated zone in absence of scattering objects) is one of the key factors ensuring the reliability of the results of inversion algorithms.[6]

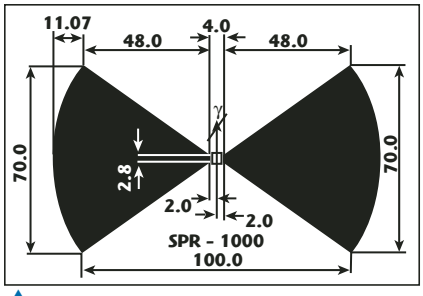


*Fig. 1 Geometry of the radiating element.*

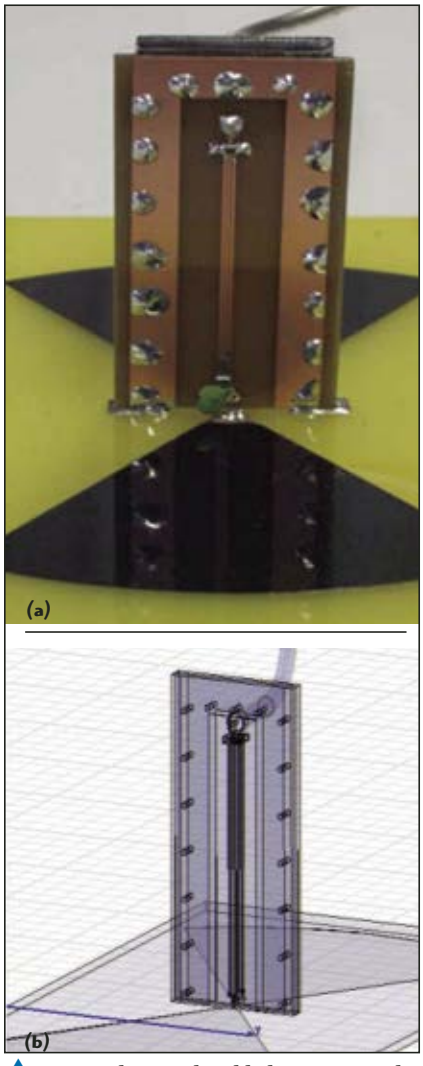


*Fig. 2 The Marchand balun circuit and the radiating elements; (a) photograph and (b) model.*

In this article, the modeling and characterization of two bow-tie antennas, designed for GPR prospecting and working in the 600 to 1400 MHz frequency band, are described. The antennas are numerically analysed in different operative situations by the well-known software High Frequency Structure Simulator (HFSS) from Ansoft[7] based on FEM,[8] which permits accurate modeling of both the feed and the radiating elements of the antennas. The numerical results are then compared with measurements collected in laboratory conditions at the Dipartimento di Ingegneria dell'Informazione of the Second University of Naples, Italy.

## ANTENNA MODEL AND SIMULATION

The two bow-tie antennas of interest have been designed and built at the Dipartimento di Ingegneria Elettronica, University of Florence, Italy, for GPR prospecting. The geometry of the radiating elements is shown in ***Figure 1***, with the dimensions given in millimeters. They are made up from a 35 µm thick copper layer, deposited on a substrate of epoxy glass FR4. A microstrip Marchand balun circuit, implemented by means of three coupled lines, provides a balanced excitation of the radiating elements. The related printed circuit is fabricated using microstrip technology on epoxy glass FR4, and is connected directly to the antenna feed. The connection on the unbalanced side uses a conformable coaxial cable. The balun is centrally positioned with respect to the antenna, as shown in ***Figure 2***. In order to achieve a negligible back radiation, the feed and radiating elements are placed into a 171.5 × 120.6 × 106.7 mm metallic box. The box is filled with five layers of dielectric absorbing material (carbon-loaded polyurethane foam) in order to reduce undesired reflections. The balun circuit is mechanically protected with a silicon varnish and by plastic material holders, fixed on two sides of the printed circuit so it does not touch the surrounding absorbing material.

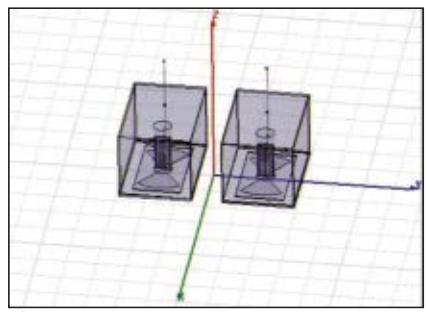

*Fig. 3 Geometry of the problem.*

The numerical analysis of the antenna has been performed for the full three-dimensional model using HFSS.[7] The geometrical model is divided into a large number of tetrahedra, where each single tetrahedron is a four-sided pyramid. This collection of tetrahedra is referred to as the finite element mesh. The curved metal surfaces of the antenna are modeled by a triangular mesh, constituted by the tetrahedra faces. The radiation boundary conditions are used for the mesh termination so as to simulate a free-space problem. The code uses an iterative process, called adaptive analysis, in which the mesh is automatically refined in critical regions: first, a solution based on a coarse initial mesh is generated; then, the mesh is refined in areas of high error density, and a new solution is generated. When some selected parameters converge to within a desired limit, the code breaks out of the loop. The structure to be simulated was described previously when the model of the balun circuit and the radiating elements were depicted.

## NUMERICAL SIMULATION AND EXPERIMENTAL RESULTS

The configuration with the two antennas close to each other, in the same plane and pointing in the same direction, is considered. This "reflection" configuration represents the typical operation situation for a GPR system. The overall geometry of interest is shown in ***Figure 3***, where the radiating elements lay in the x-y plane and are aligned along the y-axis. The UWB performance of the antenna is evaluated in terms of the scattering matrix between the input port of the transmitting antenna and the output port of the receiving antenna. The reference planes are located at the connectors on the back


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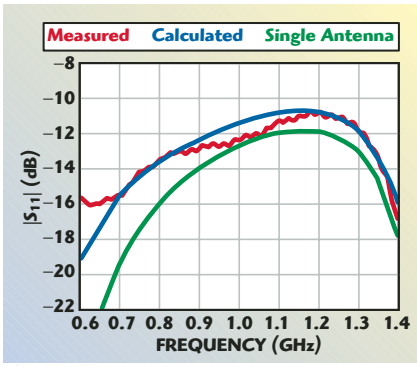


*Fig. 4 $|S_{11}|$ comparison for the free-space case.*

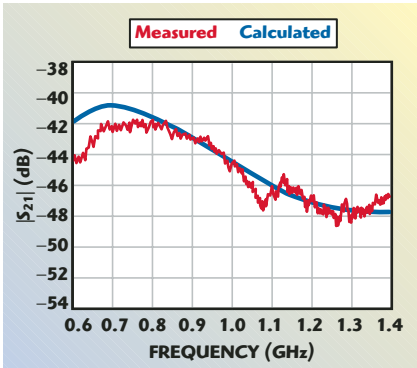


*Fig. 5 $|S_{21}|$ comparison for the free-space case.*

of the boxes enclosing the two antennas. The chosen convergence criterion of the FEM code is based on the change of the four $S_{ij}$ (i,j = 1, 2) elements of the scattering matrix between two consecutive iterations at finer meshes. If at the Nth iteration, $\Delta S$ is

$$\Delta S = \mathrm{Max}_{ij}\left|S_{ij}^{N} - S_{ij}^{N-1}\right| \qquad (1)$$

when $\Delta S \le 0.01$, the analysis stops; otherwise, it continues with a refined mesh. The computer scattering parameters have been evaluated by assuming 50 Ω for the characteristic impedance of the feed-lines. The results of the numerical analysis have been compared with measurements collected at the Electromagnetic Diagnostics Laboratory of the Second University of Naples. The measurements have been collected in a semi-anechoic environment by an automatic system for the measurement of the near field at microwaves.[9] As a fidelity index to qualify the agreement between simulated and measured scattering parameters, the correlation coefficient

$$r = \frac{\left|\int_{f_{min}}^{f_{max}} S_M(f)\,S_T^{*}(f)\,df\right|}{\sqrt{\int_{f_{min}}^{f_{max}} |S_M(f)|^2\,df}\;\sqrt{\int_{f_{min}}^{f_{max}} |S_T(f)|^2\,df}} \qquad (2)$$

is adopted, where $S_M(f)$ and $S_T(f)$ denote the measured and the numerically calculated scattering matrix elements, respectively, and * stands for the complex conjugate. The integrals are performed over the whole frequency band of the antenna.

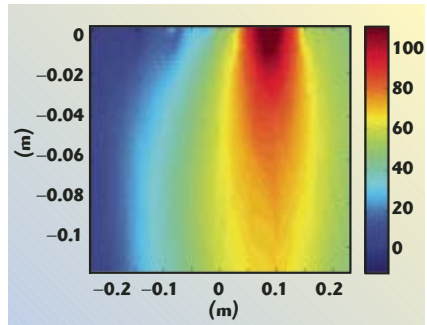


*Fig. 6 Amplitude of the x-component of the electric field in the computation domain.*

### The Free-space Case

The first analysis is performed for radiation in free-space. The two antennas are spaced 15 cm away from each other. The scattering parameter $S_{11}$, which accounts for the influence of the receiving antenna on the mismatching of the transmitting one, is considered. ***Figure 4*** shows the comparison between the measured (red line) and the computed (blue line) amplitude of the scattering parameter $S_{11}$, whereas the value computed for a single antenna case (green line) is displayed for comparison to better appreciate the proximity effect between the antennas. As can be seen, the agreement between measurement and computation is good and r = 0.77. Then, the scattering parameter $S_{21}$, which accounts for the mutual coupling between the transmitting and receiving antenna, is considered. ***Figure 5*** shows the comparison between the measured and computed values with r = 0.9. The analysis in free-space is completed by evaluating the near field, that is the field inside the computation domain; ***Figure 6*** shows the amplitude of the x-compo-

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| VLF-225 | DC-225 | 350 | 460 | VLF-1700 | DC-1700 | 2050 | 2375 |
| VLF-320 | DC-320 | 460 | 560 | VLF-1800 | DC-1800 | 2125 | 2425 |
| VLF-400 | DC-400 | 560 | 660 | VLF-2250 | DC-2250 | 2575 | 2900 |
| VLF-490 | DC-490 | 650 | 800 | VLF-2500 | DC-2500 | 3075 | 3675 |
| VLF-530 | DC-530 | 700 | 820 | VLF-2600 | DC-2600 | 3125 | 3750 |
| VLF-575 | DC-575 | 770 | 900 | VLF-2750 | DC-2750 | 3150 | 4000 |
| VLF-630 | DC-630 | 830 | 1000 | VLF-2850 | DC-2800 | 3300 | 4000 |
| VLF-800 | DC-800 | 1075 | 1275 | VLF-3000 | DC-3000 | 3600 | 4550 |
| VLF-1000 | DC-1000 | 1300 | 1550 | VLF-5000 | DC-5000 | 5580 | 6850 |
| VLF-1200 | DC-1200 | 1530 | 1865 | VLF-6000 | DC-6000 | 6800 | 8500 |
| VLF-1400 | DC-1400 | 1700 | 2015 | VLF-6700 | DC-6700 | 7600 | 9300 |

***U.S. Patent Numbers 6,790,049 & 6,943,646***

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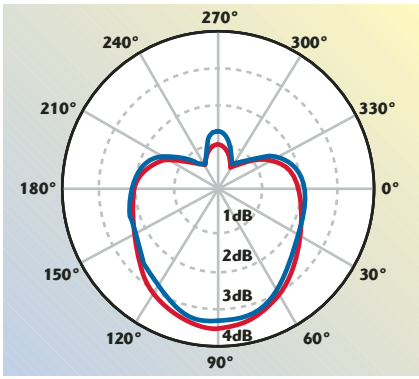


*Fig. 7 Radiation pattern in the x + z plane.*

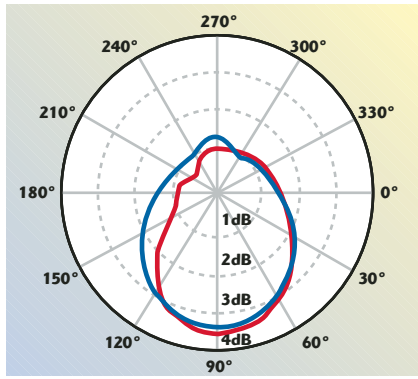


*Fig. 8 Radiation pattern in the y - z plane.*

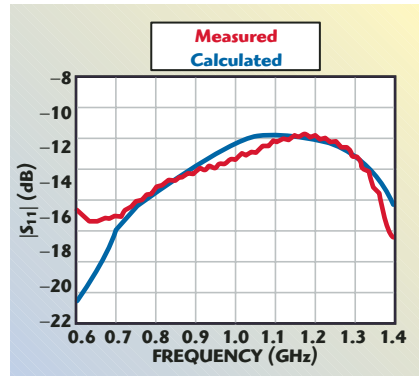


*Fig. 9 $|S_{11}|$ comparison for the antennas close to masonry.*

nent of the electric field. Finally, in ***Figures 7*** and ***8***, the radiation patterns in the two x-z and y-z principal planes are shown as calculated by the HFSS software from the computed near field for two close antennas (red line) and the single antenna case (blue line), respectively. As can be appreciated, the proximity of the receiving antenna causes an asymmetrical radiation pattern in the y-z plane.

### The Tuff Masonry Case

In the second analysis, the case of the two antennas placed in front of a tuff masonry is considered. The distance between the antennas and the masonry is 3.5 cm. The thickness of the masonry is 11 cm. The electromagnetic behaviour of tuff has been characterized previously[10] and a relative dielectric constant equal to 4 and a conductivity equal to 0.01 S/m are assumed. ***Figure 9*** shows the comparison between the numerically evaluated and the measured magnitude of the scattering parameter $S_{11}$. The correlation index is r = 0.77. The scattering parameter $S_{21}$ is also considered. In this case, a good agreement is observed between the numerically evaluated and the measured scattering parameters (see ***Figure 10***). The correlation index is r = 0.96. Finally, ***Figure 11*** shows the amplitude of the x-component of the electric field in the computation domain; inside the masonry, the stationary behavior of the field is observed due to standing waves propagation inside the masonry.

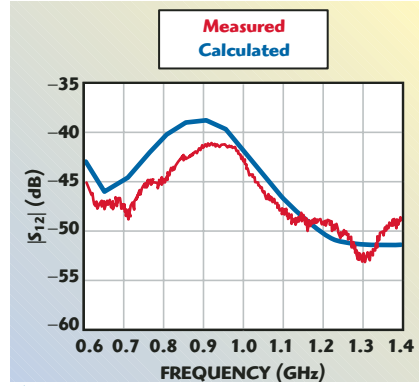


*Fig. 10 $|S_{12}|$ comparison for the antennas close to masonry.*

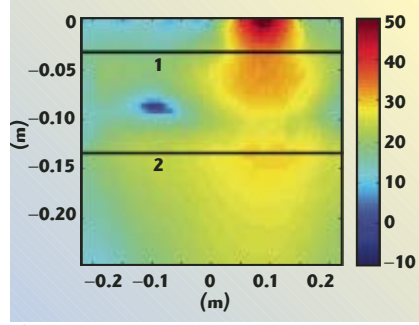


*Fig. 11 Amplitude of the x-component of the electric field.*

## CONCLUSION

This article shows how a FEM-based numerical analysis, accounting for the full complexity of a bow-tie antenna, and the results of experimental measurements agree well to characterize UWB sensors, both in free-space and in the more challenging case of a non-homogeneous scenario. This work falls within the more general activity on sensor characterization developed at the Second University of Naples and at IREA. The final goal of this accurate modeling aims to improve the reconstruction of tomographic images in inverse scattering problems. ■

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**Francesco Soldovieri** *received his Laurea degree in electronic engineering from the University of Salerno, Italy, in 1992, and his PhD degree in electronic engineering from the University of Naples, Italy, in 1996. In 1993, he joined the electromagnetic research group of the University of Naples and held a postdoctoral fellowship at the same university from 1998 to 1999. In 1999 to 2000, he collaborated with the research group on applied electromagnetism at the Second University of Naples. Since 2001, he has been a researcher at the Institute for the Electromagnetic Sensing of the Environment of the Italian National Research council (IREA-CNR). His research interests include electromagnetic diagnostics, inverse scattering and GPR applications.*

**Adriana Brancaccio** *received her Laurea degree summa cum laude in electrical engineering in 1991 and her PhD degree in 1994 from the University of Naples, Italy. Since 1994, she has been an associate researcher and, from 2001, a professor of electromagnetics in the department of information engineering at the Second University of Naples, where she is in charge of the applied electromagnetics laboratory. Her research interests include nonlinear inverse scattering problems, subsurface sensing and scattered field measurements.*

**Giovanni Leone** *received his degree in electronic engineering in 1981 from the University of Naples, Italy. From 1986 to 1992, he was an associate researcher in electromagnetics at the University of Salerno, Italy. Since 1992, he has been an associate professor, first at the University of Salerno and, since 1995, at the Second University of Naples. In 2000, he became a full professor at the University of Reggio Calabria, where he is responsible for the funding from the Italian Space Agency and from the National Research Council. Since 1999, he has been a member of the scientific committee of CREATE. He cooperated with SUPELEC in Paris and in research activities about inversion algorithms for subsurface radar within a program funded by the Ministry of Scientific Research. His research interests include the properties of radiated fields with application to antenna measurement techniques, inverse problems in antenna synthesis, phase retrieval of radiated fields and more recently inverse scattering for material diagnostics and buried objects sensing.*

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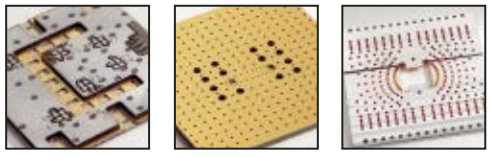

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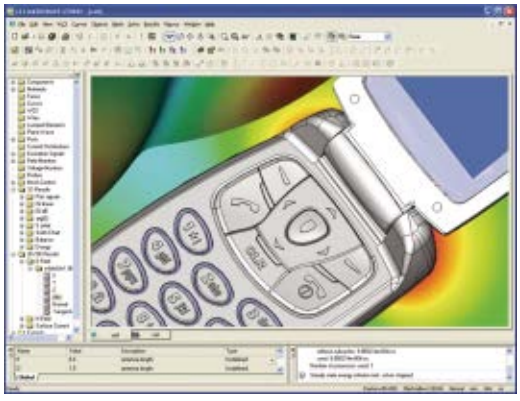

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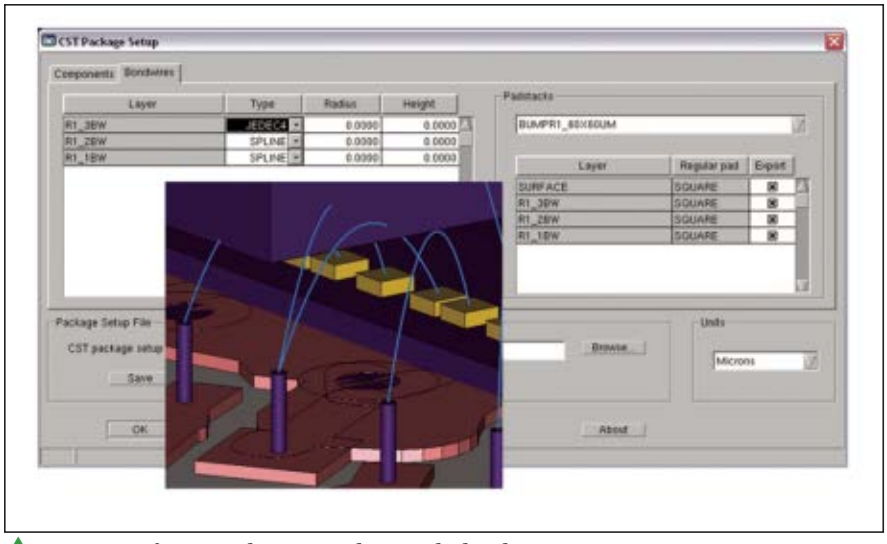



▲ *Fig. 1 Interface to Cadence APD showing the bondwire setup.*

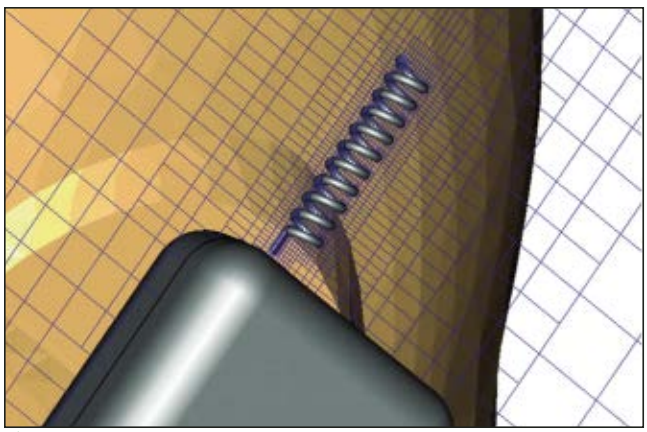
A starting point for many passive simulations is the requirement to import a legacy or previous generation design available in either a mechanical CAD tool like Pro/E or a layout tool like Cadence Allegro. The latest Cadence interface is shown in ***Figure 1***, where bondwire properties can now be included. Most engineers would rather not rebuild the model in a new interface no matter how good it is. However, the problem has always been that the electomagnetic simulation requirements are tough compared to the mechanical requirements.

Version 2006B of CST MWS takes a large step forward in this area by introducing a method called Fast Perfect Boundary Approximation (FPBA). PBA itself was a breakthrough back in 1998 when the first version of CST MWS was launched. It allowed a time domain technique to represent curves and inclines very accurately by applying an integral approach to solving Maxwell's equations. FPBA takes another major step forward, by enabling the fast and robust discretization of imported models, including those corrupt geometrical descriptions. This removes the tedious stage of "healing" a model. The title picture shows a complex cell phone simulated in the software.

## FLEXIBLE SUBGRIDDING IN THE TIME DOMAIN

A vastly challenging blue-sky research project, subgridding has tested the brightest minds, but the release is now here and it provides an exciting breakthrough in time domain technology. Flexible subgridding combines CST's existing PBA and TST (thin sheet technology) with true general conforming behavior.

While there are commercial products available that subgrid rectangular volumes, they lack flexible and conforming behavior and are limited to "staircase" representation of objects. The breakthrough in CST MWS comes with the combination of many technologies to make a truly adaptive and numerically stable scheme without sacrificing existing benefits.



▲ *Fig. 2 Antenna next to a head showing the effect of the new subgridding scheme.*

***Figure 2*** illustrates where the scheme is most applicable — models where there are large differences in scale. In this case a human head and the small helix of a cell phone antenna where time domain's traditional uniform grid requires extension of the mesh cells to the boundary of the problem. The new method allows a "focus" of mesh cells around the small helix feature with a progression to large cells away from the feature where there is smaller spatial field variation. Mesh cells can be split in either x, y, or z directions or all three depending on the structure. For example, a planar structure would require a split in only one plane to correctly capture the metal edge behavior. In the illustrated example, the reduction in cell count is huge at over 10:1 with an even larger ratio reduction in overall run time.

## WHY INCLUDE OTHER SOLVERS?

The history of CST MICROWAVE STUDIO® is based in the time domain where many years of research and development and constant updates have produced the world's most successful tool in its class. However, despite having the ability to solve a vast array of problems, in particular large or broadband devices, other techniques have shown advantages for certain classes of problem. A frequency domain method based on tetrahedral meshing with adaptive meshing and fast-frequency sweep was introduced in version 5.1 primarily to focus on the subset of problems where the technique excelled. These included narrow band or electrically smaller devices such as a high Q filter, a SiP with a coil over a substrate or a phased-array antenna (see ***Figure 3***). One overriding goal of its introduction was to ensure that the interface was completely common to the time domain solver, so that the user simply had to press "T" or "F" to start the appropriate solver.

2006B completes the set of features required for a world-class frequency domain solver, including both direct or iterative techniques, first- and second-order approaches, advanced Delaunay volume meshing, slanted ports, plane wave excitation, multi-frequency mesh adaption and Floquet boundaries for unit cell phased-array structures. ***Figure 4***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| **FPD750DFN** | 20 | 24 | 38 | 0.3 | 11.5* | 24 | 38 | N/A | 5 | 230 |
| **FPD750SOT343** | 18 | 20 | 38 | 0.3 | 8* | 20 | 38 | N/A | 3.3 | 230 |
| **FPD6836SOT343** | 20 | 20 | 32 | 0.5 | 9* | 19 | 32 | 1.2 | 3 | 105 |

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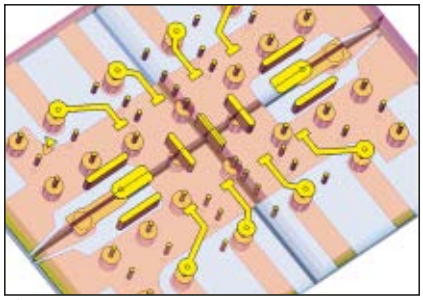

Fig. 3 SiP 3D model.

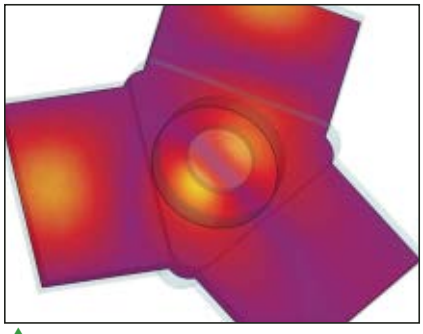

Fig. 4 A circulator solved in the frequency domain with slanted ports.

shows a circulator example solved with slanted ports.

## NEW SOLVER

2006B introduces a brand new specialist full-wave solver for the solution of electrically very large structures where the structure is perhaps 10s or 100s of wavelength in size. Examples may include antenna interoperability studies or radar illumination of an aircraft. This Integral Equation solver uses the multi-level fast multipole method (MLFMM). A special approach to solving the method of moments (MoM) technique, including only having a surface mesh, the MLFMM solver has several key advantages. Traditional MoM solvers are great for simple metallic or wire type antennas where there is only a small surface to mesh and lots of free space. Large and complex devices become troublesome due to the coupling of every element required in the scheme leading to a large, dense matrix. Scaling for such problems is notoriously bad and they quickly become insoluble. The new method's multi-level function reduces full coupling to within multiple small cubic volumes of the model. These are then coupled in a similar way to a larger volume and so on recursively until one volume remains. Scaling for numbers of cells is vastly improved at

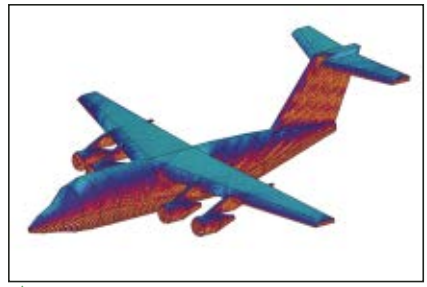

Fig. 5 A surface current plot of an illuminated 120 wavelength long aircraft solved with the new Integral Equation Solver.

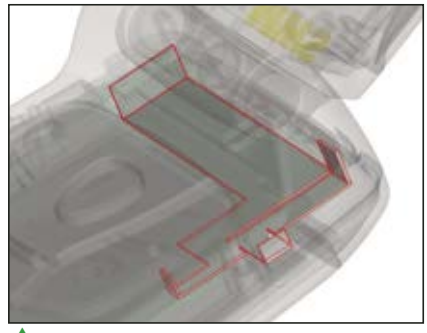

Fig. 6 Hover Selection allows easy viewing and selection of embedded parts.

Nlog(N). This new specialist solver fits into the existing interface framework. ***Figure 5*** shows an aircraft simulated with the new solver.

To round out the list of solvers available in 2006B, improvements have been made to the established eigenmode (E) solver including speed improvements and the ability to select a frequency window for modes, rather than calculating all modes from 0 Hz. The Fast Resonant (R) solver continues to provide lightning quick S parameter calculations of high Q filters.

The general-purpose time and frequency domain solvers will suit the vast majority of applications, but the three specialist solvers will help the engineer solve niche problems quickly and accurately.

## MODELER AND OTHER IMPROVEMENTS

Many improvements will benefit the user in version 2006B. To allow for the trend of ever more complex models, the front-end modeler includes a feature reduction on movement to guarantee 15 frames per second. Hover Selection allows easy selection of parts and hidden parts (see ***Figure 6***) in the view or the navigation tree. Smart View rotation automatically centers rotation at the mouse. In post-processing, Adaptive Vector Plots plots an appropriate number of vectors according to the zoom level.

Switching between low and high frequency simulation is now a one-button operation and the menus and icons automatically reconfigure. Coupling of magnetostatic and high frequency solvers is complete, so that biased ferrites can be solved in devices such as circulators. Coupled thermal simulation is also available.

CST DESIGN STUDIO,™ an entry-level circuit simulation alternative to ADS from Agilent or Microwave Office from AWR, now has a time domain solver, allowing eye diagram creation, for example.

## CONCLUSION

2006B may sound like an intermediate release; however, this must be one of the most understated names in commercial computational electromagnetics. CST has recognized that the world of RF, microwave and high speed design is rapidly evolving and moving toward ever-greater complexity. The combination of world-class solvers and a leading-edge interface has also evolved to meet that challenge head-on. With the multiple benefits of faster throughput and lowered design cost and risk, engineers and their managers may want to look at this release more closely. A no-obligation 30-day trial can be arranged by contacting the company via e-mail at info@us.cst.com.

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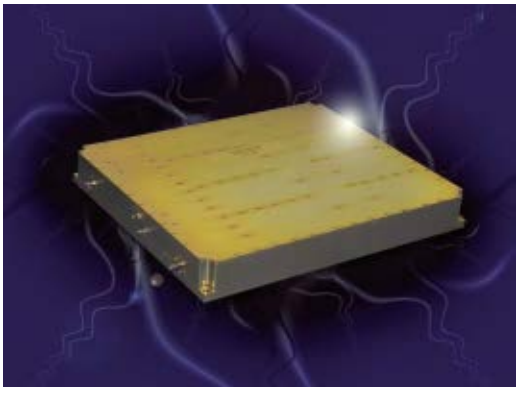


# A 20 TO 2500 MHz, 20 W SOLID-STATE AMPLIFIER

Aethercomm is introducing a new super broadband 20 to 2500 MHz, single module, 20 W solid-state power amplifier. The model SSPA 0.020-2.500-20 amplifier was designed and manufactured for several different platform types. The US military is transitioning to software-defined radios that cover the majority of this bandwidth. Existing systems employ two or even three amplifiers to cover the 20 to 2500 MHz bandwidth. For medium power missions, the new broadband solid-state amplifier can be a single module solution for the entire bandwidth.

Modern electronic warfare systems operate over these bands and utilize exciters that drive multiple power amplifiers to accomplish the system requirements. This new multi-octave amplifier can enable these systems to be smaller in volume and lower in DC power consumption as one amplifier can now replace two or even three existing amplifiers.

The actual applications for this amplifier are numerous. This unit may be employed in any system that requires high power, flat gain and high linearity over the full amplifier bandwidth. The amplifier could be employed in test equipment, communication systems or general lab use. The processes used in its manufacture make this RF module extremely rugged and make it useful in a ground vehicular environment, sheltered or unsheltered shipboard environment or airborne inhabited or uninhabited environment.

## HIGH PERFORMANCE OVER A BROAD BANDWIDTH

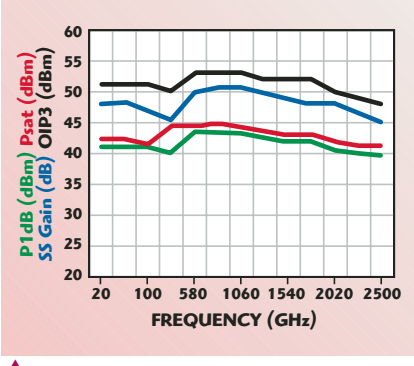
This super broadband amplifier successfully covers the full 20 to 2500 MHz bandwidth with high gain, high power, an extremely flat gain response and a high OIP3 across the band. The most difficult design challenge the designers faced was capturing the low frequency response. These types of designs typically require ferrite devices to achieve the low frequency responses. This new design was ultimately able to balance the high end of the

AETHERCOMM INC.
*San Marcos, CA*

**TABLE I**

**SSPA 0.020-2.500-20 TYPICAL PERFORMANCE AT 25°C**

| Frequency (MHz) | P1dB (dBm) | Current @ P1dB (Amps) | 2nd Harmonic @ P1dB (dBc) | 3rd Harmonic @ P1dB (dBc) | Small-signal Gain (dB) | PSat (dBm) | OIP3 (dBm) | PAE @ PSat (%) |
|---|---|---|---|---|---|---|---|---|
| 20 | 41.5 | 6.1 | –20 | –20 | 48.0 | 42.4 | 51 | 10.2 |
| 50 | 41.2 | 6.1 | –20 | –21 | 48.3 | 42.4 | 51 | 10.2 |
| 100 | 41.2 | 6.1 | –21 | –20 | 47.0 | 41.4 | 51 | 8.1 |
| 340 | 40.2 | 5.9 | –24 | –21 | 45.5 | 44.5 | 50 | 17.1 |
| 580 | 43.4 | 5.9 | –24 | –19 | 50.0 | 44.5 | 53 | 17.1 |
| 820 | 43.5 | 6.0 | –21 | –20 | 50.5 | 44.9 | 53 | 18.4 |
| 1060 | 43.5 | 5.8 | –16 | –21 | 50.5 | 44.3 | 53 | 16.6 |
| 1300 | 42.7 | 6.1 | –14 | –20 | 49.5 | 43.9 | 52 | 14.3 |
| 1540 | 42.0 | 6.2 | –18 | –23 | 48.5 | 43.0 | 52 | 11.5 |
| 1780 | 42.0 | 6.0 | –26 | –40 | 48.0 | 43.0 | 52 | 11.9 |
| 2020 | 40.6 | 6.0 | –20 | –43 | 48.0 | 42.0 | 50 | 9.4 |
| 2260 | 40.0 | 6.0 | –23 | –37 | 46.5 | 41.5 | 49 | 8.3 |
| 2500 | 39.7 | 6.0 | –28 | –45 | 45.0 | 41.2 | 48 | 7.8 |




▲ *Fig. 1 SSPA 0.020-2.500-20 typical performance at 25°C.*

band with the low end, while achieving the required high power and flat gain.

Designed for rugged military applications, the SSPA 0.020-2.500-20 broadband amplifier operates from +28 VDC. The quiescent current from the +28 V supply is approximately 5 amps. Under drive the current will go up to approximately 6 amps. At saturated output power the efficiencies are typically 10 to 15 percent over most of the band. A listing of the RF amplifier's performance can be found in ***Table 1***.

The RF performance of this amplifier is exceptional for the bandwidth covered. The gain of the amplifier is 45 to 50 dB with a typical gain flatness of ±2.5 dB, and can be flattened further if required. The 1 dB compression point (P1dB) of this unit is 41 to 43 dBm over most of the band. The saturated output power (PSat) of this RF module is 42 to 44 dBm over most of the band. The measure of linearity used to characterize the amplifier was its output intercept point (OIP3). The OIP3 of this amplifier is typically 51 to 53 dBm across the majority of the band. Another important parameter of super broadband amplifiers is in-band harmonics. The Aethercomm solution has typical in-band harmonics of –20 dBc for the second- and third-harmonics at P1dB. A graphical representation of the amplifier's performance is found in ***Figure 1***. The typical noise figure of this unit is 8.0 dB in the small-signal region of operation. Input and output VSWR is 2.0 maximum.

The SSPA 0.020-2.500-20 amplifier offers many standard and self-protection features that make it robust in demanding environments. The unit offers over-voltage protection with under-voltage lock out. Reverse polarity protection is standard on the amplifier. The RF module is protected from an open or short circuit placed on the RF output connector via a bad cable or antenna. There is an internal DC blanking function that enables and disables the RF devices in 5000 ns maximum. This feature is employed if there is a receiver used in conjunction with the power amplifier or if a "look through" function is required in an EW jamming system. In standby mode, the amplifier draws 100 mA maximum.

The amplifier is packaged in a modular housing that is 10.0 by 12.0 inches and 1.5 inches in height. The typical weight of the amplifier is 7.5 pounds. The input and output RF connectors are SMA female type. DC and command/control functions are employed via DC feed through capacitors.

## CONCLUSION

Aethercomm has successfully manufactured a 20 to 2500 MHz solid-state RF power amplifier capable of 10 to 20 W P1dB across the full band. The saturated output power is 15 to 30 W across the full band. This super broadband unit is currently available today in small piece quantities or for high volume manufacturing. In addition, higher output power is available. Additional information may be obtained by contacting sales@aethercomm.com.

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| ZX60-2534M | 0.5-2.5 | 38.0 | 3.1 | +30.0 | 15.9 | 5.0 | 185 | 64.95 |

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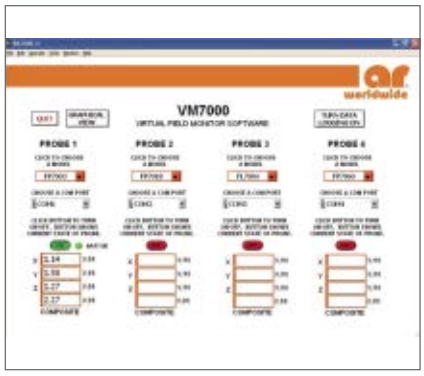
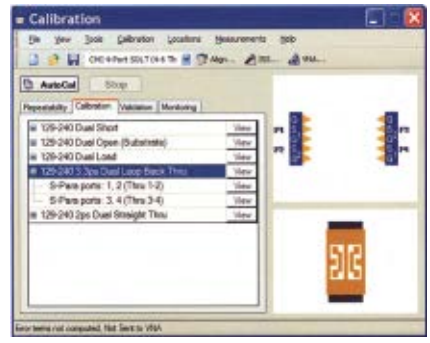



## VIRTUAL FIELD MONITOR

The virtual field monitor provides a graphical user interface that allows control of all probe function and displays probe data and status. It simultaneously controls and operates up to four probes – a combination of AR's three laser or six battery-powered E and H field probes and runs under Windows NT, 2000 or XP operating systems. Model VM7000 and the company's field monitor, FM7004, complete a high technological line of EMC field monitoring products.

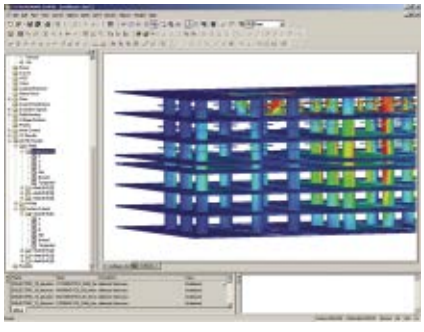
***AR Worldwide RF/Microwave Instrumentation,***
***Souderton, PA (215) 723-8181, www.ar-worldwide.com.***
***RS No. 310***




## AUTOMATIC CALIBRATION SOFTWARE

WinCal™ 2006 is the company's next gen vector network analyzer calibration software platform. It provides users a precision one-, two-, three- and four-port RF calibration/measurement tool as well as many powerful features that remove the complexity of using a VNA. Its guided and intelligent system configuration, Wizards and Tutorials allow both new and experienced users to get started quickly, producing accurate and reliable RF measurements.

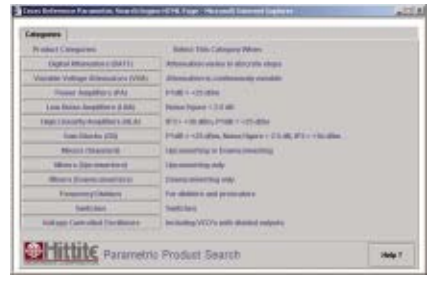
***Cascade Microtech Inc.,***
***Beaverton, OR (503) 601-1000, www.cascademicrotech.com.***
***RS No. 311***



## SOFTWARE UPGRADE

CST STUDIO SUITE™ 2006B is a significant software upgrade that will allow research and development engineers involved in the design of high frequency components, wireless communications, EMC and signal integrity to benefit from the augmented functionality and interoperability of this latest release. Solver technology has again been a key focus of CST STUDIO SUITE™'s development. Users of CST MWS' Time Domain solver can now take advantage of the new *Fast PBA* mesher for higher performance and robustness, and a more flexible subgridding scheme with drastically reduced memory requirements. The transient solver engine is the first module to run with Linux operating systems. The Frequency Domain solver features plane wave incidents and slanted ports and the performance of mesher and solver has been increased.

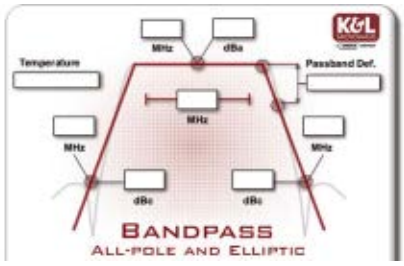
***CST GmbH,***
***Darmstadt, Germany +49 (0) 6151/7303-0, www.cst.com.***
***RS No. 312***




## PARAMETRIC PRODUCT SEARCH TOOL

The parametric product search tool is designed for the RF engineer to specify important product parameters and view the company's products that match a specific requirement in a specification-compliance format. Unlike conventional search engines which eliminate products that narrowly fall outside of specification, the parametric product search tool can show these products allowing the engineer to make intelligent design trade-off decisions to "fine tune" the requirement to specific needs. View this and other product software support tools including Product Cross Reference, PLL Phase Noise and Mixer Spur Chart Calculators on the company's site.

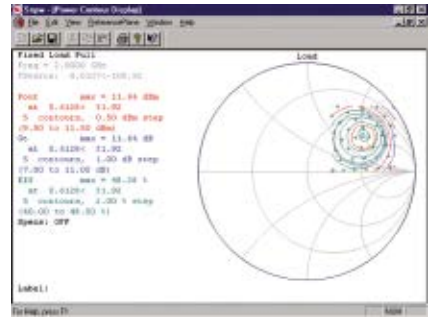
***Hittite Microwave Corp.,***
***Chelmsford, MA (978) 250-3343, www.hittite.com.***
***RS No. 313***




## FILTER SYNTHESIS AND SELECTION TOOL

The Filter Wizard™ service enables engineers to shorten RF and microwave filter design cycles. It is a Web-based solution that helps design engineers effectively select and confirm the feasibility of RF and microwave filter products for applications, from defense, telecommunications and aerospace. Filter Wizard is utilized for front-end design efforts as well as re-designs or general testing purposes. The on-line application provides companies with a significant competitive advantage by eliminating specification errors and freeing up valuable engineering resources.

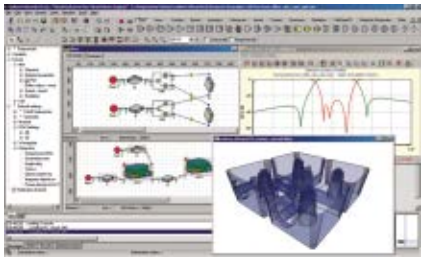
***K&L Microwave Inc.,***
***Salisbury, MD (410) 749-2424, www.klfilterwizard.com.***
***RS No. 314***




## AUTOMATED TUNER SYSTEM

The Automated Tuner System (ATS) software version 4.00.05 has recently been released. The ATS provides extensive device characterization with any common stimulus. This includes load/source pull, VSWR circles, various types of swept measurements and the new Advanced Sweep Plan. The Advanced Sweep Plan provides a multi-dimensional characterization with up to seven independent variables including power, bias and frequency. Custom or proprietary measurements may be added in the open drivers or user functions. Also, the software is a dynamic link library (DLL), and sample programs in C++, Visual Basic, Agilent VEE, or Labview show how to extend the functionality to meet additional requirements.

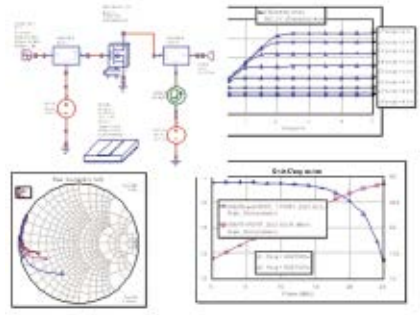
***Maury Microwave Corp.,***
***Ontario, CA (909) 987-4715, www.maurymw.com.***
***RS No. 315***



## EM-SOFTWARE TOOL

Version 6.0 is the recent release of the company's EM-software tool µWave Wizard.™ This release provides the seamless integration of 3D FEM simulation technology into the existing mode-matching and 2D FEM framework. This includes optimization, full 3D visualization of the electromagnetic fields, calculation of material and finite wall conductivity losses. The consideration of draft angles for die-casting technology and the modeling of arbitrarily shaped probes in cavities will be possible with new, flexible library elements. User-defined geometries can now be imported as STL files. The mesh generation process is fully automated.

***Mician GmbH,***
***Bremen, Germany +49 (421) 168 993 51, www.mician.com.***
***RS No. 316***



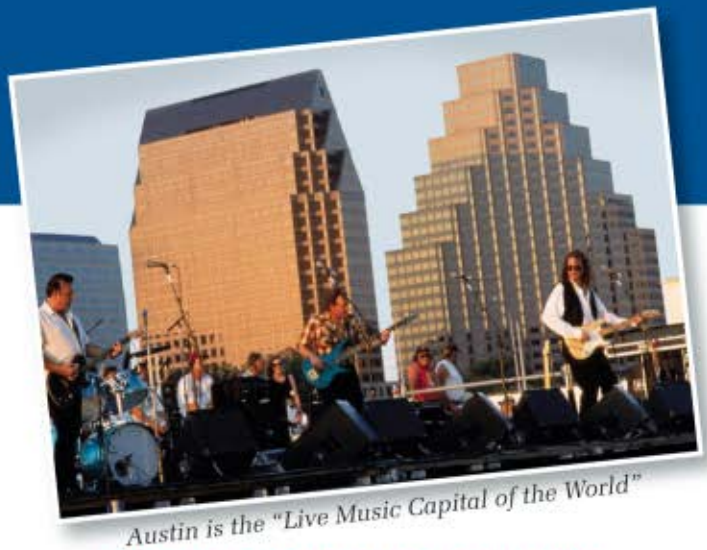
## NONLINEAR TRANSISTOR AND DIODE LIBRARIES

The powerful and feature-rich Nonlinear Transistor (NLT) and Diode (NLD) model libraries for Applied Wave Research Microwave Office have been released. These NLT and NLD libraries comprise high accuracy nonlinear, high frequency and noise models for BJT, HBT, MESFET, HEMT and LDMOS transistors as well as Schottky, varactor and PIN diode models representing leading semiconductor manufacturers. Unique features in these libraries include substrate scaling, bias and temperature dependence.

***Modelithics Inc.,***
***Tampa, FL (888) 359-6359, www.modelithics.com.***
***RS No. 317***

# AMTA 2006–AUSTIN, TEXAS

## Antenna Measurement Techniques Association's 28th Annual Symposium



*Austin is the "Live Music Capital of the World"*

## Come to Learn! Stay for the Fun!

- Over 100 technical papers presented on a continuous basis
- Full-day practical short course on wireless technology
- CATL lab technical tour
- "Fajita & Margarita" technical lecture night
- Social events—Companion tours, golf tournament, downtown museum dinner and special effects movie
- Exhibits by leading suppliers

**For updated info click on: www.amta.org**

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AUSTIN TEXAS Oct.22-27 2006

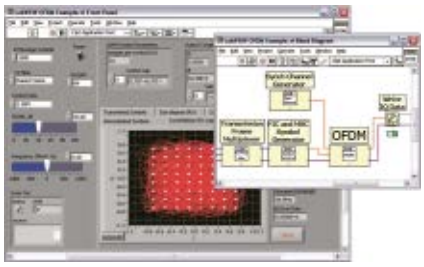
*Host Hotel:* RENAISSANCE. AUSTIN HOTEL

*Host:* ETS·LINDGREN An ESCO Technologies Company

*Co-Hosts:* ROHDE&SCHWARZ

THE UNIVERSITY OF TEXAS AT AUSTIN UT ECE ELECTRICAL & COMPUTER ENGINEERING

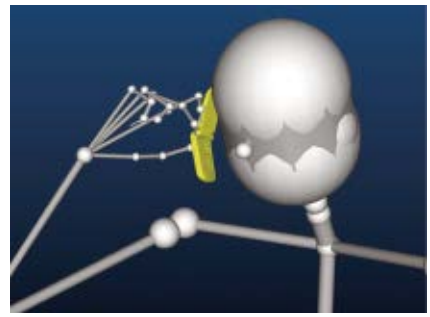
Microwave Journal




## COMMUNICATIONS TOOLKIT

Many emerging wireless standards including 4G and 802.11n are based on orthogonal frequency division multiplexing (OFDM), a bandwidth-efficient technique that increases communications system noise immunity. The latest release of the company's Modulation Toolkit for LabVIEW, which builds on a comprehensive set of signal generation, analysis, visualization and processing functions, includes downloadable OFDM examples. Version 3.1 of the toolkit provides ASK, FSK, MSK, PSK, PAM, QAM, AM, FM, PM and many of their derivatives – even generation and analysis of custom modulation formats. The NI Modulation Toolkit also comes standard with channel-coding algorithms such as Reed-Solomon and filtering algorithms such as Gaussian that improve transmission efficiency and noise immunity to serve countless communications applications.

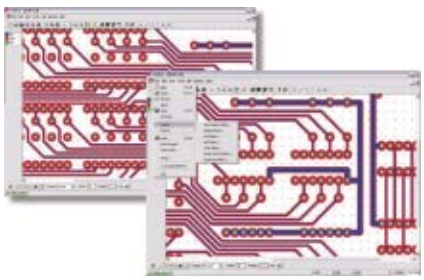
***National Instruments Corp.,***
***Austin, TX (800) 813-3693, www.ni.com.***
***RS No. 318***



## HUMAN BODY ANALYSIS TOOL

The release of VariPose v1.2 provides many new features and enhancements. Users will immediately notice that it has the head of the skeleton figure. Used for model manipulation, it now offers additional features such as ears and nose. Also, CAD objects may be imported into the skeleton model space for accurate positioning of the body. Other enhancements include: auto-selection of skeleton joints, improved mouse control of 3D mesh view, improved project creation and file handling, improved cropping of mesh model, improved Zoom and Pan, and updated icon set and background.

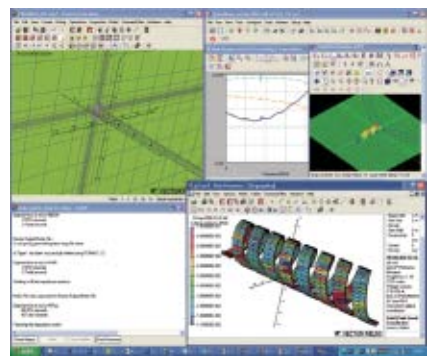
***Remcom Inc.,***
***State College, PA (814) 861-1299, www.remcom.com.***
***RS No. 319***



## ISOPRO 2.6 SOFTWARE

Isopro 2.6 is the company's latest version of software and introduces a new range of features. The company's powerful DXF system is cutting edge and can handle the latest AutoCAD 2006 files. The addition of the new DXF system in combination with updated OrCAD and other format upgrades makes the Auto Import feature stronger than before. The company added functionality to drive new machine hardware and a new set of reorder functions. This software remains a leading DFX and Gerber Editor.

***T-Tech Inc.,***
***Norcross, GA (770) 455-0676, www.t-tech.com.***
***RS No. 320***



## RF/MICROWAVE SIMULATION SOFTWARE

Concerto v6, the new version of its integrated software for RF and microwave design, has just been released. The suite includes Conforming FDTD analysis, Moment Method analysis and Finite Element analysis modules, all running within a single environment. The optimization module has been enhanced and a 64-bit Linux version included. "Concerto Essential" is also available as a low cost entry-level option. Concerto is now integrated into AWR's Microwave Office® circuit design platform. The link allows users of Microwave Office to obtain accurate FDTD calculations of component S-parameters and radiation patterns, simply by calling Concerto from within the Office environment.

***Vector Fields Inc.,***
***Aurora, IL (630) 851-1734, www.vectorfields.com.***
***RS No. 321***

# Ultra Wideband VCOs

## FEATURED MODELS

| Model # | Frequency (MHz) | Tuning Voltage (VDC) | Typical Phase Noise @10 kHz (dBc/Hz) | Bias Voltage (VDC) |
|---|---|---|---|---|
| DCFO Series | | | | |
| DCFO35105-5 | 350 to 1050 | 0 to 25 | -112 | +5 |
| DCMO Series | | | | |
| DCMO514-5 | 50 to 140 | 0.5 to 24 | -105 | +5 |
| DCMO1027 | 100 to 270 | 0 to 24 | -112 | +5 to +12 |
| DCMO1129 | 110 to 290 | 0.5 to 24 | -112 | +5 to +12 |
| DCMO1545 | 150 to 450 | 0.5 to 24 | -108 | +5 to +12 |
| DCMO1857 | 180 to 570 | 0.5 to 24 | -108 | +5 to +12 |
| DCMO2476 | 240 to 760 | 0.5 to 24 | -105 | +5 to +12 |
| DCMO3288-5 | 320 to 880 | 0.5 to 24 | -109 | +5 |
| DCMO60170-5 | 600 to 1700 | 0 to 25 | -99 | +5 |
| DCMO100230-12 | 1000 to 2300 | 0.5 to 24 | -101 | +12 |
| DCMO100230-5 | 1000 to 2300 | 0.5 to 24 | -98 | +5 |
| DCMO150318-5 | 1500 to 3200 | 0.5 to 20 | -93 | +5 |
| DCMO150320-5 | 1500 to 3200 | 0.5 to 20 | -95 | +5 |
| DCMO190410-5 | 1900 to 4100 | 0 to 15 | -90 | +5 |

**Features:**

- Ultra Wide Bandwidth
- High Immunity to Phase Hits
- Exceptional Phase Noise
- Very Low Post Thermal Drift
- Small Size Surface Mount
- Lead Free - RoHS Compliant
- Patent Pending
- REL-PRO® Technology


RoHS COMPLIANT

*For additional information,*
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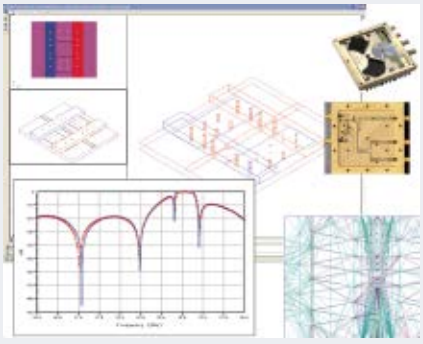
*201 McLean Boulevard, Paterson, NJ 07504*
*Phone: (973) 881-8800 Fax: (973) 881-8361*
*E-mail: sales@synergymwave.com*

SYNERGY® MICROWAVE CORPORATION

*Visit Our Website At WWW.SYNERGYMWAVE.COM*

*The following booth numbers are complete as of July 19, 2006.*

## Electromagnetic Design System



The Electromagnetic Design System (EMDS) 2006A makes full 3D EM simulation an economical option for designers working with RF circuits, MMICs, PC boards, modules and signal integrity applications. EMDS provides the best price performance 3D EM simulator, with a full 3D electromagnetic field solver, a modern solid modeling front-end and fully automated meshing and convergence capabilities for modeling arbitrary 3D shapes such as connectors, machined parts, components, bond wires, antennas and packages.

***Agilent Technologies Inc., EEsof Division, Santa Rosa, CA (800) 829-4444, http://eesof.tm.agilent.com.***
***Booth 529*** ***RS 216***

## Measuring Receiver

The N5531S measuring receiver is a built-in measuring receiver personality for its PSA series of high performance spectrum analyzers. Excellent measurement accuracy and sensitivity, with frequency coverage to 50 GHz, make this solution ideal for signal generator and attenuator calibration, from audio to millimeter-wave frequencies. Each measuring receiver function can be initiated by pressing just one button on the front panel. The N5531S turns the PSA into a measuring receiver and minimizes investment in test equipment.

***Agilent Technologies Netherlands, Amstelveen, The Netherlands 31-20-5472367, www.agilent.com.***
***Booth 301*** ***RS 217***

## Traveling Wave Tube Amplifiers

Models 125T18G26 and 125T26G40 are traveling wave tube microwave amplifiers (TWTA) that deliver 125 W across the 18 to 40 GHz range. Model 125T18G26 operates in a frequency range from 18 to 26.5 GHz, while model 125T26G40 operates in the 26.5 to 40 GHz range. These TWTAs are designed for applications where wide instantaneous bandwidth, high gain and higher power output is required.

***AR Worldwide RF/Microwave Instrumentation, Souderton, PA (215) 723-8181, www.ar-worldwide.com.***
***Booth 413*** ***RS 267***

## PLL Synthesizers, Transmitters and Transceivers

These PLL synthesizers, transmitters and transceivers are offered in single and dual PLLs, Fractional-N and Integer-N and feature good phase noise performance and integration. The ADF700x transmitters and ADF702x transceivers provide low cost, robust, short range wireless connections. Both licensed and unlicensed sub-1 GHz frequency bands can be addressed. Additionally, software tools such as the ADIsimPLL® and ADIismLINK™ are available to greatly speed the time to market of the final product.

***Analog Devices Inc., Norwood, MA (781) 329-4700, www.analog.com.***
***Booth 317/319*** ***RS 218***

## Handheld Base Station Analyzer

The MT8222A BTS Master is a lightweight, handheld base station analyzer that provides wireless field technicians with a single test solution for installing, deploying and maintaining today's complex wireless networks. Weighing only 3.6 kgs, the MT8222A BTS Master packs a complete set of tools that includes cable and antenna analysis, spectrum analysis, power meter, WCDMA/HSDPA and GSM/GPRS/EDGE RF and demodulation, WCDMA/HSDPA over the air (OTA), interference analysis, bit error rate tester (BERT), channel scanner and power monitor, eliminating the need for technicians to carry several instruments in the field.

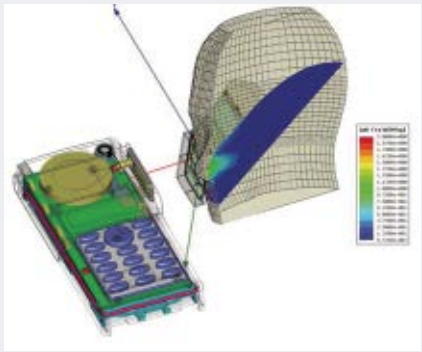
***Anritsu EMEA Ltd., Luton, Bedfordshire (+44) 1582 433433, www.anritsu.com.***
***Booth 101*** ***RS 219***

## Signal Integrity Design Suite

The AWR SI 2006 design suite is a cross-domain signal integrity solution specifically developed for designing and analyzing high frequency, high speed electronics circuits. Engineers can now identify, analyze and fix signal integrity issues early in the design cycle, ensuring that the designs work correctly the first time. SI 2006 combines the unique AWR design environment and unified data model with a signal integrity analysis environment, providing comprehensive, easy-to-use analysis capabilities that work seamlessly in one platform.

***Applied Wave Research, El Segundo, CA (310) 726-3000, www.appwave.com.***
***Booth 308*** ***RS 221***

## RF Design Suite



Due to the complexities of today's high frequency and high speed component designs, design re-spins can be commonplace and expensive, but are avoidable using the Ansoft RF Design Suite. Comprising the powerful harmonic-balance and transient circuit simulator Nexxim dynamically linked with the electromagnetic software HFSS for the S-parameter and full-wave SPICE extraction of high frequency and high speed components, the Ansoft RF Design Suite enables complete circuit and system analysis to be performed.

***Ansoft, Basingstoke, Hampshire +44 1256 347788, www.ansoft.com.***
***Booth 201/203*** ***RS 220***

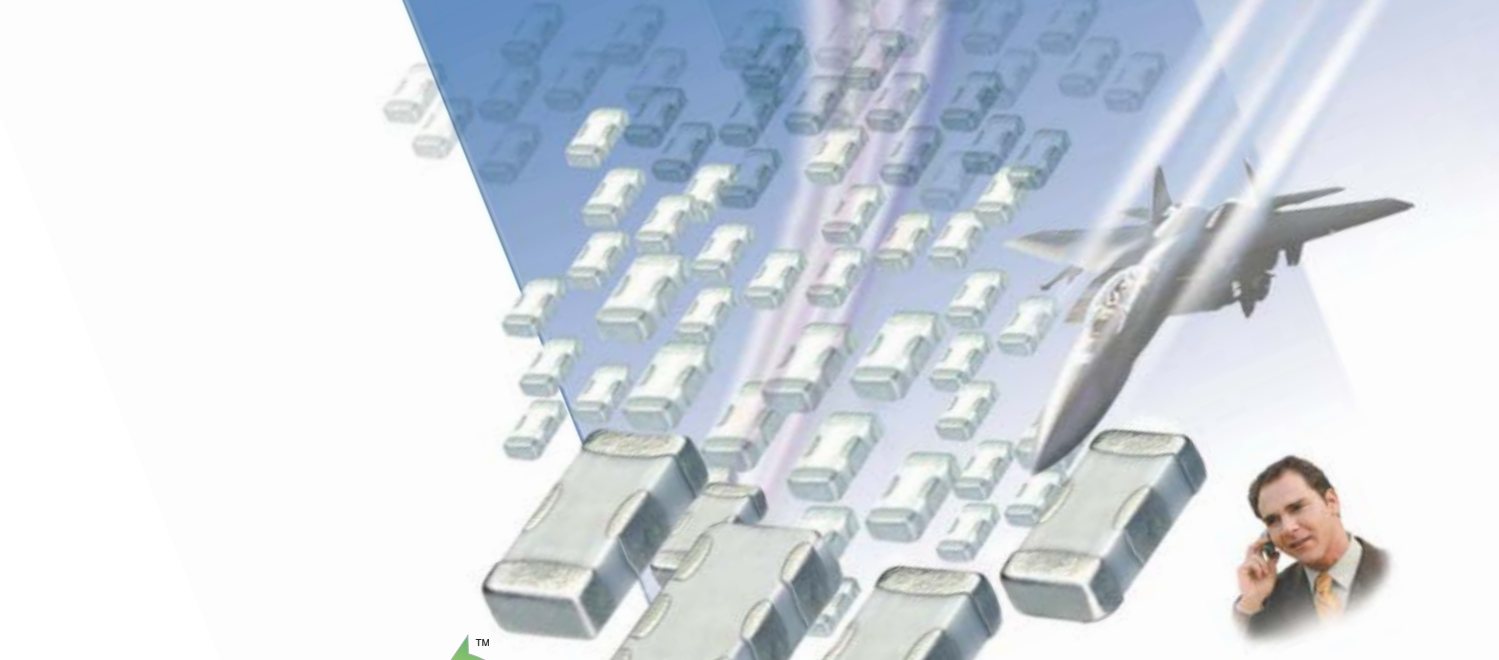
## Microwave Laminate

The CLTE-XT microwave laminate is a reinforced PTFE/micro-dispersed ceramic that offers good dielectric temperature/phase stability and "Best-in-Class" insertion loss, loss tangent (0.0012 at 10 GHz), low CTExyz (8, 8, 20) and low thermal coefficient of dielectric loss (8 ppm/°C) for applications that require electrical phase stability over –55° to 150°C. Applications include space and military electronics such as phase sensitive arrays for radar and antennas, RF/microwave communications, aircraft collision avoidance systems and JTRS.

***Arlon, Bear, DE (302) 834-2100, www.arlon-med.com.***
***Booth 442*** ***RS 222***

## Track-and-hold Amplifiers

The Inphi GigaTrack range of track-and-hold amplifiers are low jitter devices that support an ultra-wide analog bandwidth up to 18 GHz and operate at an impressive 2GSamples/s. Designed specifically for high performance, high speed telecommunications and instrumentation applications, in civil and military systems, applications are expected to include fast sampling oscilloscopes, and direct



# Low & High Pass FILTERS

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## *DC to 13GHz from 99¢ ea. qty. 1000

WOW! These **tiny 0.12" x 0.06"** LFCN low pass and HFCN high pass filters deliver very high rejection outside the passband and virtually eliminate PC board space demand! Choose from the world's widest selection of off-the-shelf Low Temperature Co-fired Ceramic models, all using our fully automated LTCC manufacturing process to provide tremendous cost savings that are passed on to you! These hermetically sealed filters also deliver consistent performance, superior temperature stability, and high power handling capability for a low-cost, high-value solution to give you the competitive edge! So contact Mini-Circuits today and order these tiny LFCN and HFCN filters from stock.

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### *Designer's Kits Available*

***K1-LFCN+*** Contains 35 Units: Only $99.95
5 ea. LFCN-225, 320, 400, 490, 530, 575, 630

***K2-LFCN+*** Contains 60 Units: Only $119.95
5 ea. LFCN-800, 900, 1000, 1200, 1325, 1700, 2000, 2250, 2400, 5000, 6000, 6700

***K3-LFCN+*** Contains 55 Units: Only $109.95
5 ea. LFCN-80, 95, 105, 120, 225, 320, 400, 490, 530, 575, 630

***K4-LFCN+*** Contains 90 Units: Only $175.95
5 ea. LFCN-800, 900, 1000, 1200, 1325, 1400, 1450, 1500, 1525, 1575, 1700, 1800, 2000, 2250, 2400, 5000, 6000, 6700

***K5-LFCN+*** Contains 65 Units: Only $129.95
5 ea. LFCN-2000, 2250, 2400, 2500, 2600, 2750, 2850, 3000, 3800, 4400, 5000, 6000, 6700

***K1-HFCN+*** Contains 40 Units: Only $79.95
5 ea. HFCN-650, 740, 1200, 1500, 1760, 2000, 2275, 2700

***K2-HFCN+*** Contains 50 Units: Only $99.95
5 ea. HFCN-880, 1300, 1320, 1600, 1810, 1910, 2100, 3800, 5500, 8400

LFCN & HFCN

- HFCN-3800
- HFCN-5500
- HFCN-8400

*Detailed Performance Specs and Shopping Online for these models, and our full line of SMA filters, see* ***www.minicircuits.com/filter.shtml***

LTCC TECHNOLOGY/LFCN HFCN

| Model | Passband MHz | fco, MHz Nom. (Loss 3dB) Typ. | Stopband MHz (Loss >20dB) Min. | No. Of Sections | Price $ ea. Qty. 10 |
|---|---|---|---|---|---|
| LFCN-80 | DC-80 | 145 | 200 | 7 | 3.99 |
| LFCN-95 | DC-95 | 165 | 220 | 7 | 3.99 |
| LFCN-105 | DC-105 | 180 | 250 | 7 | 3.99 |
| LFCN-120 | DC-120 | 195 | 280 | 7 | 3.99 |
| LFCN-225 | DC-225 | 350 | 460 | 7 | 2.99 |
| LFCN-320 | DC-320 | 460 | 560 | 7 | 2.99 |
| LFCN-400 | DC-400 | 560 | 660 | 7 | 2.99 |
| LFCN-490 | DC-490 | 650 | 800 | 7 | 2.99 |
| LFCN-530 | DC-530 | 700 | 820 | 7 | 2.99 |
| LFCN-575 | DC-575 | 770 | 900 | 7 | 2.99 |
| LFCN-630 | DC-630 | 830 | 1000 | 7 | 2.99 |
| LFCN-800 | DC-800 | 990 | 1400 | 5 | 1.99 |
| LFCN-900 | DC-850 | 1075 | 1275 | 7 | 1.99 |
| LFCN-1000 | DC-1000 | 1300 | 1550 | 7 | 1.99 |
| LFCN-1200 | DC-1200 | 1530 | 1865 | 7 | 1.99 |
| LFCN-1325 | DC-1325 | 1560 | 2100 | 5 | 1.99 |
| LFCN-1400 | DC-1400 | 1700 | 2015 | 7 | 2.99 |
| LFCN-1450 | DC-1450 | 1825 | 2025 | 7 | 2.99 |
| LFCN-1500 | DC-1500 | 1825 | 2100 | 7 | 2.99 |
| LFCN-1525 | DC-1525 | 1750 | 2040 | 7 | 2.99 |
| LFCN-1575 | DC-1575 | 1875 | 2175 | 7 | 2.99 |
| LFCN-1700 | DC-1700 | 2050 | 2375 | 7 | 1.99 |
| LFCN-1800 | DC-1800 | 2125 | 2425 | 7 | 2.99 |
| LFCN-2000 | DC-2000 | 2275 | 3000 | 5 | 1.99 |
| LFCN-2250 | DC-2250 | 2575 | 2900 | 7 | 1.99 |
| LFCN-2400 | DC-2400 | 2800 | 3600 | 5 | 1.99 |
| LFCN-2500 | DC-2500 | 3075 | 3675 | 7 | 1.99 |
| LFCN-2600 | DC-2600 | 3125 | 3750 | 7 | 1.99 |
| LFCN-2750 | DC-2750 | 3150 | 4000 | 7 | 1.99 |
| LFCN-2850 | DC-2800 | 3300 | 4000 | 7 | 1.99 |
| LFCN-3000 | DC-3000 | 3600 | 4550 | 7 | 1.99 |
| LFCN-3800 | DC-3900 | 4850 | 6000 | 7 | 2.99 |
| LFCN-4400 | DC-4400 | 5290 | 6700 | 7 | 2.99 |
| LFCN-5000 | DC-5000 | 5580 | 6850 | 7 | 1.99 |
| LFCN-6000 | DC-6000 | 6800 | 8500 | 7 | 1.99 |
| LFCN-6700 | DC-6700 | 7600 | 9300 | 7 | 1.99 |
| HFCN-650 | 850-2490 | 650 | 480 | 7 | 1.99 |
| HFCN-740 | 900-2800 | 740 | 550 | 7 | 1.99 |
| HFCN-880 | 1060-3200 | 880 | 640 | 7 | 1.99 |
| HFCN-1200 | 1380-4600 | 1180 | 940 | 7 | 1.99 |
| HFCN-1300 | 1510-5000 | 1300 | 930 | 7 | 1.99 |
| HFCN-1320 | 1700-5000 | 1320 | 1060 | 7 | 1.99 |
| HFCN-1500 | 1850-5500 | 1550 | 1250 | 7 | 1.99 |
| HFCN-1600 | 1950-5000 | 1600 | 1290 | 7 | 1.99 |
| HFCN-1760 | 2100-5500 | 1760 | 1230 | 7 | 1.99 |
| HFCN-1910 | 2200-5200 | 1910 | 1400 | 7 | 1.99 |
| HFCN-1810 | 2250-4750 | 1810 | 1480 | 7 | 1.99 |
| HFCN-2000 | 2410-6250 | 2000 | 1530 | 7 | 1.99 |
| HFCN-2100 | 2500-6000 | 2100 | 1530 | 7 | 1.99 |
| HFCN-2275 | 2640-7000 | 2275 | 1770 | 7 | 1.99 |
| HFCN-2700 | 3000-6500 | 2500 | 1800 | 7 | 1.99 |
| ● HFCN-3800 | 4250-10000 | 3800 | 3200 | 5 | 2.49 |
| ● HFCN-5500 | 6000-11500 | 5500 | 4500 | 5 | 2.99 |
| ● HFCN-8400 | 9000-13000 | 8400 | 6000 | 5 | 2.99 |

*LFCN = Low Pass, HFCN = High Pass*

*LFCN Models:* ***U.S. Patent #6,943,646*** *except LFCN-800,-1325,-2000 & -2400.*
*HFCN Models -3800, -5500, -8400 Patent Pending.*

★ For applications requiring DC voltage applied to the input or output, add suffix letter "D" to model number (DC resistance to ground is 100 megaohms min.) and add $0.50 to unit price.

***For RoHS compliant requirements, ADD + SUFFIX TO BASE MODEL No.*** *Example: LFCN-80+*
*All Kits* ***RoHS*** *compliant only.*

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# NEW WAVES

conversion receivers in radios, radar or electronic warfare systems, all of which require analog-to-digital conversion of high frequency signals.

***Aspen Electronics,***
***Middlesex, England +44 (0) 20 8868 1311,***
***www.aspen-electronics.com.***
***Booth 112/114/116*** ***RS 223***

## Millimeter-wave Integrated Circuits

This family of millimeter-wave integrated circuits has been expanded to include low cost, surface-mount amplifiers that operate in the 18 to 30 GHz range. These surface-mount devices offer performance comparable to the "bare-die" ICs to the full extent of their frequency range. The model AMMP-6233 is a low noise amplifier that operates from 18 to 30 GHz and model AMMP-6130 is a multiplier with amplifier that provides up to 30 GHz output.

***Avago Technologies,***
***Boeblingen, Germany +49 (0)6441-92460,***
***www.avagotech.com.***
***Booth 344*** ***RS 224***

## High Power Isolator

This high power isolator is designed for telecom satellite payloads. The model offers a 205 W CW, 10 dB multipactor margin, 0.15 dB insertion loss and 320 g mass. Based on the company's space heritage of 12 years, it is continuously improving the power level behavior. Other coaxial access and drop-in ferrite isolators are available for space applications (space heritage upon request).

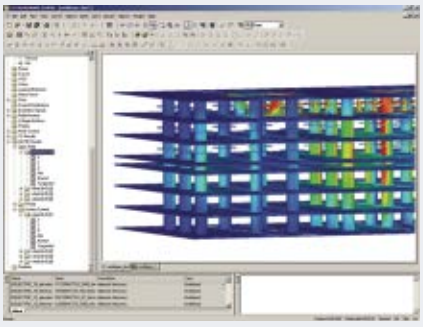
***Chelton Telecom & Microwave,***
***Paris, France +33 (0)1 69 02 25 60,***
***www.chelton-tm.com.***
***Booth 517*** ***RS 225***

## Waveguides

These waveguides have been produced on unmanned machinery and electronically deburred. The Yorkshire-based company, which has recently made significant investments in new equipment and extended production facilities, provides a method that features quality, consistency and value.

***Claro Precision Engineering Ltd.,***
***Knaresborough, North Yorkshire***
***+44 (0) 1423 867 413, www.claro.co.uk.***
***Booth 334*** ***RS 226***

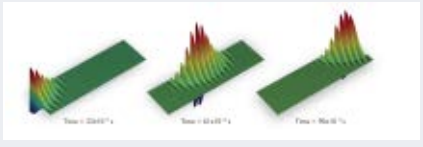
## 3D EM Time Domain Tool



CST MICROWAVE STUDIO® 2006B offers augmented functionality and interoperability to design engineers involved in the design of high frequency components, wireless communications, EMC and signal integrity, in terms of speed, ease of use and accuracy. Improved and extended solver technology includes the addition of an Integral Equation solver for electrically large structures, a new Fast PBA mesher for higher performance and robustness, and a new flexible subgridding scheme, which drastically reduces memory requirements.

***CST–Computer Simulation Technology,***
***Darmstadt, Germany +49 6151 7303-0,***
***www.cst.com.***
***Booth 307*** ***RS 227***

## Electromagnetics Simulation Software



An add-on to COMSOL Multiphysics, the electromagnetics module focuses on component design in virtually all areas where engineers need electromagnetic field simulations – from statics and quasistatics to microwaves and photonics. The static, transient and frequency-domain analyses allow for material properties that are complex-valued, anisotropic, frequency or time-dependent. Simulation outputs are electromagnetic field distributions, resistance, inductance, capacitance and S-parameters. Lumped parameters can be exported to and extensively postprocessed in the COMSOL Script programming environment.

***COMSOL Inc.,***
***Burlington, MA (781) 273-3322,***
***www.comsol.com.***
***Booth 234*** ***RS 228***

## Stainless Steel SMA Connectors

The Johnson® line of stainless steel SMA connectors meets or exceeds the performance requirements of MIL-PRF-39012. All designs are based on a 50 Ω system impedance per MIL-STD-348 and operate at frequencies up to 26.5 GHz minimum. All contacts are plated with 50 micro-inches of gold for good durability and high frequency performance. The right angle PC mount jack features a rigid one-piece swept contact.

***Emerson Network Power***
***Connectivity Solutions,***
***Waseca, MN (800) 247-8256,***
***www.emersonnetworkpower.com/connectivity.***
***Booth 102*** ***RS 229***

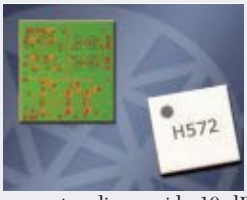
## High Power Terminations

An extensive range of high power terminations from 6 to 60 GHz has been added to the company's series of SATCOM products, which also include switches and combining/redundancy networks and filters. Convection cooled models are available up to 3 kW CW with powers of 10 kW achievable by forced air cooling. Both rectangular and double ridge waveguide models are available, with a return loss typically better than 28 dB. The units are weatherproofed and utilize low out-gassing materials throughout.

***Flann Microwave,***
***Bodmin, Cornwall +44 (0) 1208 77777,***
***www.flann.com.***
***Booth 348*** ***RS 230***

## MMIC I/Q Downconverters

These I/Q downconverter MMICs, which are available in bare die and SMT packaged formats, are ideal for microwave radio applications from 7 to 27 GHz. The HMC5570, HMC571 and HMC572 GaAs MMIC I/Q downconverter die provide 10 dB conversion gain, 3 dB noise figure and 17 dB image rejection. These integrated downconverters incorporate a LNA, image-reject mixer and a LO doubler. The image-reject topology eliminates thermal noise at the image band, while the internal ×2 LO multiplier reduces the LO frequency requirement. The HMC567LC5, HMC568LC5, HMC569-LC5, HMC570LC5, HMC571LC5 and HMC572LC5 I/Q downconverters provide RF frequency coverage from 7 to 27 GHz and are housed in RoHS compliant 5 × 5 mm leadless SMT packages.




***Hittite Microwave Corp.,***
***Chelmsford, MA (978) 250-3343,***
***www.hittite.com.***
***Booth 323/422*** ***RS 231***

## Outdoor Test Cables

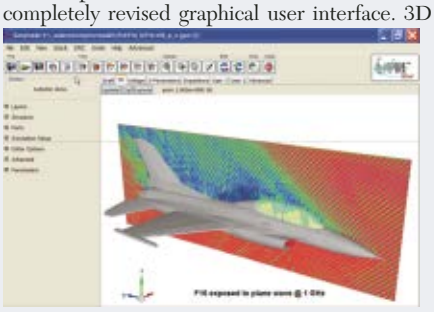
The 18 GHz SUCOTEST 18A are ruggedized, outdoor, armored test cables that provide good durability and reliable stability versus bending and torsion, while remaining exceptionally flexible. Performances are ideal for applications such as outdoor and on-site tests of wireless communication systems for the location and identification of cable and antenna system

faults, for the measurements of isolation and gain, for the design, deployment and optimization of wireless devices and networks. These cables are suitable for tests in harsh environments typical of space and defense purposes.

***HUBER+SUHNER,***
***Herisau, Switzerland +44 (0) 71 353 41 11,***
***www.hubersuhner.com.***
***Booth 223/322*** ***RS 232***

## EM Field Solver

The Empire XCcel™ is a 3D EM field solver that offers engineers a completely revised graphical user interface. 3D editor, job control and postprocessing are integrated into one frame and simulations can be adapted from templates. Further, a kernel acceleration can be obtained by a smart cache management.



***IMST GmbH,***
***Kamp-Lintfort, Germany +49 (0) 2842 981 100,***
***www.imst.de.***
***Booth 336*** ***RS 233***

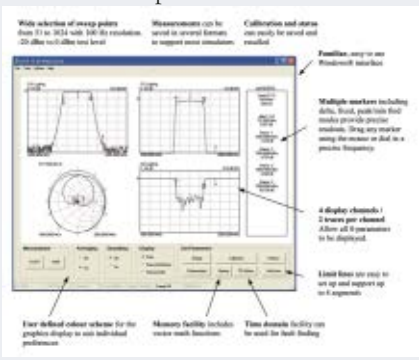
## Flexible Film Magnetic Materials

These flexible film magnetic materials combine a wide range of magnetic properties with ease of application and forming. These materials can be applied for suppression of various types of EM noise inside electronic devices, absorption of incoming EM radiation and enhancement of coupling between RFID elements in the lower microwave range from 100 MHz to 30 GHz. The company is introducing new flexible film material for RFID applications at 13.56 MHz and Nano magnetic materials for technological and biomedical applications.

***Iskra Feriti,***
***Ljubljana, Slovenija +386 (0)1 583 31 00, www.iskra-feriti.si.***
***Booth 547*** ***RS 234***

## Vector Network Analyzer

The model LA19-13-02 is a low cost vector network analyzer (VNA) that features a full S-parameter test set. This model is a PC-driven instrument that operates in a frequency range from 3 to 3000 MHz and offers a host of features such as full 12-term error correction, de-embedding, peak value search, time domain and AM-PM measurement. This VNA has four display channels offering a wide choice of display formats and its small size makes it highly portable.



***LA Techniques Ltd.,***
***Notts, England +44 (0)1636707642, www.latechniques.com.***
***Booth 446*** ***RS 235***

## Rotary Waveguide Joints

These in-house manufactured U-style rotary waveguide joints offer good performance to in-line rotary joints in broadband applications. Particularly suitable for use with SATCOM rotating dish antennas, the AM-RJU series rotary joints are available in a variety of sizes for the C, X and J frequency bands. These joints feature a maximum continuous power rating of 500 W and are precision engineered to ensure a maximum insertion loss of only 0.15 dB, with a typical VSWR of 1.2.

***Link Microtek Ltd.,***
***Basingstoke, Hampshire***
***+44 (0)1256 355 771,***
***www.linkmicrotek.com.***
***Booth 423/528*** ***RS 236***

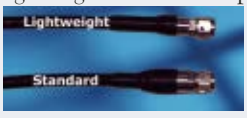
## PCB Prototype System

The LPKF ProLegend is a fast and easy to use system designed to create professional legend print on PCB prototypes. This environmentally friendly product does not require screen printing and comes with all the necessary tools and consumables included. The LPKF ProLegend requires little training; a user with no previous knowledge can master the system immediately and effectively. The ProLegend allows legend printing to be an easy in-house process, increasing security and eliminating production delays.

***LPKF Laser & Electronics,***
***Wilsonville, OR (503) 454-4212, www.lpkfusa.com.***
***Booth 333/335*** ***RS 237***

## Lightweight Cable Assemblies

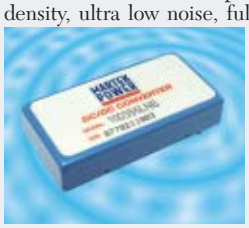
These lightweight cable assemblies utilize the FN34RXLW cable, a new lightweight version of its proven FN34RX cable assemblies. This new product offering is intended for use in military airborne applications and is available in all popular assembly configurations featuring reduced mass and volume. Complementing the lighter FN34RXLW cable, all assemblies now feature new reduced weight and volume connectors. The connectors retain the conventional ETNC, SMA and N interfaces while incorporating new materials. Excess bulk has been excluded to decrease both weight and space. Electrical specifications for all assemblies based on the new lightweight cable and connectors remain unchanged, with no change in VSWR, insertion loss or environmental characteristics.




***M/A-COM,***
***Lowell, MA (800) 366-2266, www.macom.com.***
***Booth 206*** ***RS 238***

## Low Noise DC/DC Converters

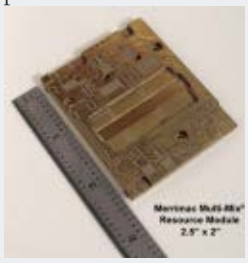
The LNB series is a new product family of high density, ultra low noise, fully isolated DC/DC converters. This series offers output ripple of 10 mVp-p and operates over input voltage ranges of 4.5 to 7 VDC, 8 to 16 VDC and 18 to 36 VDC, making them ideally suited for embedded signal processing applications. Packaged in an industry standard size of 1" × 2" × 0.4", these low profile DC/DC LNBs feature a rated power of 10 W and precisely regulated single output voltages of 3.3, 5, 12 and 24 V. Efficiency is over 85 percent.



***Martek Power Inc.,***
***Los Angeles, CA (310) 202-8820,***
***www.martekpower.com.***
***Booth 544*** ***RS 239***

## Integrated Platform Technology

The company has recently been granted a patent for its Multi-Mix® Microtechnology entitled "Coupler Resource Module." The advanced capabilities of Multi-Mix proprietary integrated platform technology provide low cost high power RF amplifier circuitry with best in class performance and density in small lightweight modules. The Resource Module is the foundation or the building block for providing Total Integrated Platform Solutions for a wide range of RF and microwave subsystems. Based on Multi-Mix proprietary PTFE process technology, the Resource Module paves the way for direct integration of high power RF circuitry with transistor die in small lightweight modules thereby eliminating discrete transistor packages and solutions.



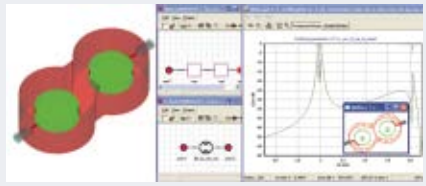
***Merrimac Industries Inc.,***
***West Caldwell, NJ (973) 575-1300,***
***www.merrimacind.com.***
***Booth 122*** ***RS 240***

## YIG-tuned Oscillators

The MLX "O" series of YIG-tuned oscillators operate in a frequency range from 6 to 20 GHz. These three models provide low phase noise performance covering 8 to 18 GHz, 6 to 18 GHz and 8 to 20 GHz. Phase noise performance of –123 dBc/Hz at a 100 kHz offset is guaranteed at 20 GHz. –125 dBc/Hz at a 100 kHz offset is guaranteed at 18 GHz. Typical performance is –128 dBc/Hz and –130 dBc/Hz at 100 kHz, respectively. Utilizing new SiGe transistors, these units are available in three standard package configurations that include 1.25" cube, 1.75" cylinder and 1" cube. Delivery: four weeks.

***Micro Lambda Wireless Inc.,***
***Fremont, CA (510) 770-9221,***
***www.microlambdawireless.com.***
***Booth 007/009*** ***RS 241***

## Fast EM CAD and Optimization Tool

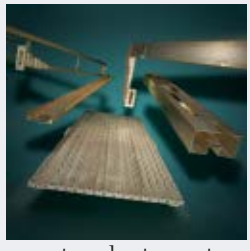


WASP-NET® version 6.3 ends the quest of "power-users" for a new quality of EM CAD and optimization speed. WASP-NET's pioneering, unique hybrid MM/FE/MoM/FD CAD engine combines the efficiency and flexibility advantages of four solvers in one single tool. Features include: fast optimization of all types of waveguide components and aperture antennas; full-wave synthesis of extended combline, cross-coupled waveguide and LTCC filters by filter wizards; dielectric resonator filters; dielectric loaded horns with shaped subreflectors; large slot arrays; multiprocessor and advanced 64-bit options.

***Microwave Innovation Group (MiG) GmbH and Co. KG,***
***Bremen, Germany +49 421 22 37 96 60,***
***www.mig-germany.com.***
***Booth 523*** ***RS 242***

## Microwave Components

These microwave components are designed for manufacturers of radar-installations and related hardware. Areas of production excellence include: standard aluminum waveguide and flange stock extrusions (wide stock available), aluminum waveguide components and antennas to customer-design. The company is operating to military as well as ISO standards with a team of dedicated professionals using in-house technologies such as precision extrusion, machining, surface treatment and assembly.



***Mifa Aluminum bv,***
***Venlo, The Netherlands***
***+31 (0) 77 389 88 88, www.mifa.nl.***
***Booth 349*** ***RS 243***

## 2.5 to 6 GHz Amplifiers

The release of IEC 61000-4-3 Edition 3 outlines a new requirement for testing up to 6 GHz presenting those EMC labs with an existing amplifier capability to 3 GHz, with a procurement challenge of how best to fill this gap. The new MILMEGA 2.5 to 6 GHz range is designed for this purpose. It also provides the perfect solution for testing against WiMAX requirements. The AS2560 range offers all the attributes of the MILMEGA series 2000 range (upgradeable in power and frequency, good power density for broadband amplification and a five-year warranty).

***MILMEGA Ltd.,***
***Ryde, Isle of Wight, UK***
***+44 (0) 1983 618004, www.milmega.com.***
***Booth 606*** ***RS 244***

# NEW WAVES

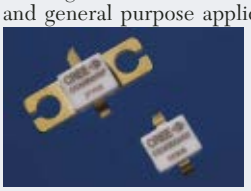
## Pre-matched HBT Power Amplifiers

Models CHV2707, CHV2710 and CHV2711 are internally pre-matched power amplifiers designed for linear WiMAX applications at 700 MHz, 2.5 GHz and 3.5 GHz. These devices are processed in a highly repeatable InGaP high voltage HBT process and include on-chip diodes for ESD protection. The devices achieve 11 dB of gain and less than 2.5 percent EVM at 30 dBm output power, with an OFDM input signal and a peak-to-average ratio (PAR) of 9 dB. The devices operate off a single supply voltage up to 12 V and include internal active bias circuitry. The CHV family includes the added feature of analog adjustment of bias current to address a variety of applications.


***Mimix Broadband Inc.,***
***Houston, TX (281) 988-4600, www.mimixbroadband.com.***
***Booth 412*** ***RS 245***

## Microwave Power from GaN

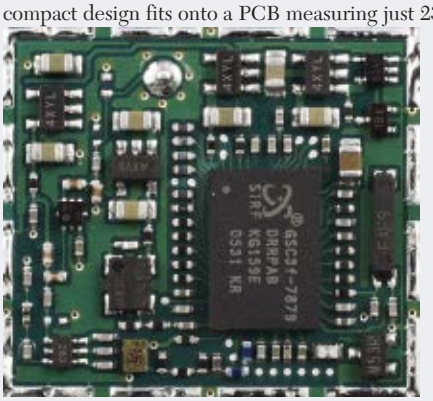
Cree's gallium nitride (GaN) HEMT devices are designed for WiMAX and general purpose applications. These devices exhibit outstanding bandwidth, high gain, excellent linearity and efficiency for power microwave applications thru C-band. Novacom is excited to offer Cree GaN HEMTs for a host of potential applications.



***Novacom Microwave Ltd.,***
***Nettleham, Lincoln, UK***
***+44 (0) 1522 751136, www.novacom-mwave.com.***
***Booth 514/516*** ***RS 246***

## GPS Receiver

This GPS receiver is based on the latest SiRFstar III IC, from SiRF. The compact design fits onto a PCB measuring just 23 × 26 mm, with the antenna mounted on the reverse side. This design is available for license by third parties and can be incorporated into appropriate case works or larger scale products on a client specific basis.



***Plextek Ltd.,***
***Great Chesterford, Essex, UK***
***+44 (0)1799 533 200, www.plextek.com.***

***Booth 312*** ***RS 248***

## RF Power Switching Connectors

These RF power switching connectors are surface-/edge-mounted and offer a cost-effective interconnection. This "two in one" product can serve as a replacement to existing standard RF switches by integrating the switch function into a connector receptacle. It optimizes packaging density, simplifies the printed circuit board layout and reduces the overall cost of ownership. These connectors are available in right or left versions for QMA, QN (both Quick Lock Formula certified) TNC, N and SMA interfaces. TNC RF power switching connectors feature an impedance of 50 Ω, operate in a frequency range from DC to 3 GHz and provide a typical isolation of –47 dB from DC to 1 GHz.

***RADIALL Ltd.,***
***Uxbridge, Middlesex, UK +44 (0)1895 425000, www.radiall.com.***
***Booth 418*** ***RS 249***

## Multiprocessing Software

The Parallel/Multiprocessing version of Wireless InSite v2.3 has just been released. This multiprocessor and cluster based version of the software enhances this well established and innovative, powerful propagation prediction tool. Predictions of how locations of transmitters and receivers affect signal strength are now even easier to obtain. Rough terrain, urban structures and indoor environments are easily included in the modeling process, together with accurate multi-path capabilities.


***Remcom Inc.,***
***State College, PA (814) 861-1299, www.remcom.com.***
***Booth 208*** ***RS 250***

# CLASSIFIEDS

**Wanted: Sr. Antenna Engineer** with MS in electrical engineering & 5 yrs relevant experience. Responsible for the design & development of a variety of microwave antenna types for mobile & wireless applications. Tasks include concept development through design release, leadership of a multi-disciplinary development team, technical direction & customer interface.

*Detailed job description available at* www.skycross.com
*Email résumés to* info@skycross.com

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## Welcome to EuMW2006

EuMW2006 is being held at the GMEX/MICC Conference Centre in the centre of the thriving city of Manchester in the UK. This is the premier European conference and exhibition for microwave, wireless communications, microwave integrated circuit and radar professionals working in industry, academia and commerce. The conference week provides a platform for revealing state-of-the-art research in these areas by focusing the sessions into four conferences:

- European Microwave Conference (EuMC) – 10-15 September.
- European Conference on Wireless Technology (ECWT) – 10-12 September.
- European Microwave Integrated Circuits Conference (EuMIC) – 10-13 September.
- European Radar Conference (EuRAD) – 13-15 September.

A range of workshops and short courses complement the regular sessions and start on Sunday 10th September. We have had a record year for paper submissions and whilst we are maintaining the same number of sessions, delegates are encouraged to attend more than one conference as the number of parallel sessions have been reduced and spread out to make it easier to benefit from this unique event. This year we expect over 1500 conference delegate registrations and over 4000 visitors to the 250 plus exhibitors, at this exciting venue.

Manchester benefits from excellent hotels, restaurants and facilities close to GMEX, and easy access from its international airport, rail and road networks. A range of exciting social events are being organised to complement the technical side of the conference and provide a chance for colleagues and friends to exchange ideas.

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The 36th European Microwave Conference

WIRELESS TECHNOLOGY 2006

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EuRAD 2006

European Radar Conference

EuMIC 2006
European Microwave Integrated Circuits Conference

Formerly GAAS Symposium

Visit http://mwj.hotims.com/7962-45 or use RS# 45 at www.mwjournal.com/info

# NEW WAVES

## WiMAX Solutions

These MMICs, transistors, hybrids and power amplifier modules are designed for both 2.5 and 3.6 GHz WiMAX applications utilizing the company's GaN technology. Currently under development and planned for release in September are 75 and 140 W power amplifier pallets for WiMAX 3.6 GHz applications. The company has plans to introduce lower frequency devices after providing a solution for this frequency.


***RFHIC,***
***Suwon, Korea +82-31-250-5000,***
***www.rfhic.com.***
***Booth 432*** ***RS 252***

## High Frequency Circuit Material

The RO4450B™-dx Bondply is a high fill/flow version of the RO4450B™ high frequency circuit material. RO4450B circuit material is a glass-reinforced hydrocarbon/ceramic thermoset bondply designed for performance-sensitive, multilayer printed circuit boards. These bondplys are designed to offer superior high frequency performance and low cost circuit fabrication. The result is a low loss material, which can be fabricated using standard epoxy/glass (FR4) processes. The new RO4450B-dx is a high fill/flow version of the RO4450B bondply. It is designed to fill those high density designs while still offering thin dielectric spacing.

***Rogers Corp.,***
***Rogers, CT (860) 774-9605,***
***www.rogerscorporation.com.***
***Booth 215/217*** ***RS 253***

## Network Analyzer

The R&S ZVA family is a network analyzer that operates in a frequency range up to 40 GHz. The R&S ZVA40 is a high-end network analyzer with a frequency range from 10 MHz to 40 GHz. Featuring a unique output power of typically better than 18 dBm, a dynamic range of typically wider than 150 dB and a high measurement speed of 3.5 µs per test point, the R&S ZVA40 is an ideal instrument for universal measurements in the microwave range. Applications include filter, mixer and amplifier tests in R&D, measurements on wafers in chip production and antenna measurements in the radar/satellite domain.

***Rohde & Schwarz,***
***Munich, Germany +49 180 512 4242,***
***www.rohde-schwarz.com.***
***Booth 501/503*** ***RS 254***

## Quick-lock Connectors

These QN connectors are based on the company's N connectors' interface that operate in a frequency range up to 11 GHz. The quick lock coupling mechanism allows fast, easy and reliable connections in the tightest spaces. The company's current product spectrum covers straight and right angle plugs as well as panel jacks for various cables (UT 141, RG 58, RG 213, RG 214, RG 223). The product range is completed by N (female) and QN (male) adapters. QN and standard N connectors are not intermateable. QN connectors have recently been QLF®-qualified.

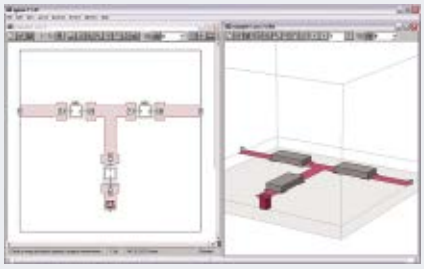
***Rosenberger Hochfrequenztechnik GmbH & Co. KG,***
***Fridolfing, Germany +49 8684-18-263,***
***www.rosenberger.de.***
***Booth 107*** ***RS 255***

## Near-field Analysis

*iSAR* is a breakthrough in dosimetric nearfield analysis. This device fully and reliably (< 0.5 dB) characterizes the RF performance of transmitters within less than 3s under fully loaded testing conditions. The device is optimized for informed go/no go decisions on the manufacturing line. This device is also an effective R&D tool for analyzing and optimizing any kind of handheld, body-mounted or implanted RF device.

***Schmid & Partner Engineering AG ,***
***Zurich, Switzerland +41 44 245 9700,***
***www.speag.com.***
***Booth 415/417*** ***RS 256***

## High Frequency EM Simulation



The company has recently announced the new Sonnet Suites Release 11. In Release 11, Sonnet introduces a calibrated internal port that exhibits exceptional dynamic range, and can be used for accurate attachment points of active or passive components. The new ports also enable full co-simulation of surface-mount part models within the EM analysis environment. Sonnet also announces a redesigned and seamless GUI interface to the Agilent ADS suite.

***Sonnet Software Inc.,***
***North Syracuse, NY (315) 453-3096,***
***www.sonnetsoftware.com.***
***Booth 212*** ***RS 257***

## Multi-channel Rotary Joint

This multi-channel rotary joint features a small system and at the same time it offers a large maximum number of available channels. Its overall length (without connection cable) is 80 mm with a diameter of 60 mm. The reward for the use of super modern manufacturing technology, micro-optical components and optimized assembly procedures is the extremely low optical insertion loss. Modern high speed transmission systems especially benefit from this technology, which is best characterized by

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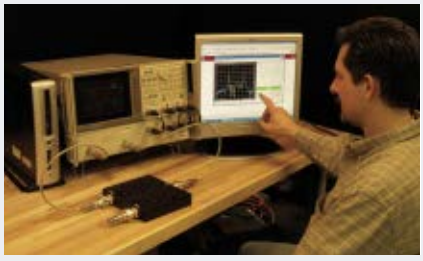
Kristen Dednah – Horizon House Publications
781-769-9750 • kdednah@mwjournal.com
**On-line registration will be open in October:**
www.mtt-sregistration.com

# NEW WAVES

an extremely low insertion loss of < 3 dB at a wavelength of 1550 nm and a high back reflection of –14 dB. The external dimensions without connecting cables add up to a total length of 135 mm at a diameter of only 60 mm.

***Spinner United Kingdom Ltd., Atherstone, Warwickshire, UK***
***+44 (0) 1827 717 777, www.spinner.de.***
***Booth 424*** ***RS 258***

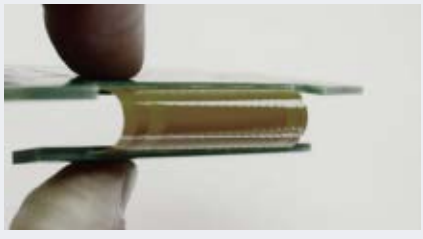
## Automated Test and Data Management Solution



The Spartan Automated Test and Data Management solution automates the characterization of microwave components and subsystems and provides data mining utilities to facilitate lean manufacturing and quality programs to create a competitive advantage. Spartan benefits include: streamlined testing reduces time, cost and errors; configuration control for test procedures; create and share test scenarios worldwide; mine the test data for opportunities to improve; robust test software for worry free operation; and compatible with all commonly used network analyzers.

***Summitek Instruments Inc., Englewood, CO (303) 768-8080, www.summitekinstruments.com.***
***Booth 119/218*** ***RS 259***

## Flexible Laminates and Bonding Materials



HyRelex is a family of low loss, high reliability, flexible laminates and bonding materials. It is constructed with the benefits of reinforced high temperature polymer chemistry to provide excellent thermal, mechanical, electrical and moisture-resistant properties. HyRelex is the best value for the high performance demands of flexible applications. The low dissipation factor, thermal stability and smooth surface-profile minimize phase shift with frequency/temperature, and yields exceptional low loss circuit performance. HyRelex is ideally suited for high frequency, high temperature and harsh environment applications.

***Taconic Advanced Dielectric Division, Mullingar, Co. Westmeath, Ireland***
***+353 44 93 95600, www.taconic-add.com.***
***Booth 239/338*** ***RS 260***

## GaAs/SAW Devices


These GaAs and SAW devices include the new model TGA4525-SM, a packaged high power amplifier for K-band applications including point-to-point radio, SATCOM and similar usages, including low cost, entry level products. Designed using the company's 0.25 micron gate power PHEMT production process, the TGA4525-SM provides nominal 37 dBm output TOI, 29 dBm of output power at 1 dB gain compression from 17 to 27 GHz with a small signal gain of 22 dB.

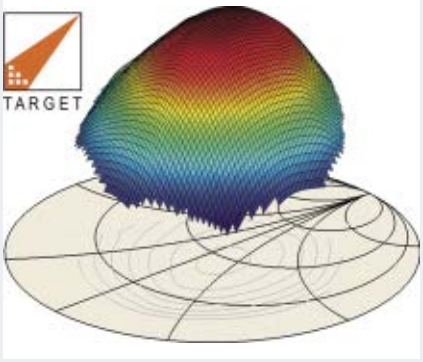
***TriQuint Semiconductor, Munich, Germany +49 89 99628 2600, www.triquint.com.***
***Booth 507*** ***RS 264***

## Voltage-controlled Oscillators


The model SLV0915C-LF is a voltage-controlled oscillator (VCO) that offers good phase noise performance for RFID applications. This VCO operates in a frequency range from 902 to 928 MHz and is designed to extend the range of RFID monitors beyond their existing range. This existing module offers phase noise performance of –123 dBc/Hz at 10 kHz offset from the carrier. This model is designed to provide good tuning linearity and good harmonic suppression of –25 dBc over the entire tuning range and makes this device an ideal choice for demanding applications. Size: 0.50" × 0.50" × 0.08". Price: $39.95 (5 pcs min). Delivery: stock to four weeks.

***Z-Communications Inc., San Diego, CA (858) 621-2700, www.zcomm.com.***
***Booth 119/218*** ***RS 266***

## Measurement and Characterization Services




The TARGET NoE, active in the fields of microwave power amplifier research and production, offer custom-made training and courses in the following fields: RF Semiconductor Materials and Devices, RF Device Characterization, RF Device Modeling, MW Power Amplifier Design, Linearization Techniques and TX Modeling.

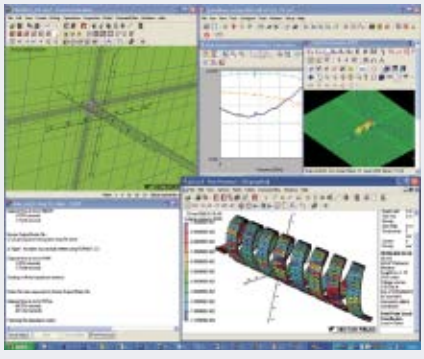
***TARGET, Vienna, Austria +43 (0) 1 50528 30-0, www.target-net.org.***
***Booth 118*** ***RS 261***

## RF/Microwave Switch Matrices

These modular microwave switch matrices operate in a frequency range from DC to 33 GHz at 50 or 75 Ω impedance and are available from compact four-terminal models to MxN rack-mounted assemblies. Switches feature repeatability of ±0.1 dB over lifetime, power to 2 kW and built-in attenuation or bypass capabilities. Assemblies contain power supplies, displays, remote control and a choice of connectors. A control module monitors cycle count, system status and redundancy. Configuration programming and customer specified interfaces are possible.

***Teledyne Electronics and Communications, Cumbernauld, Scotland +44 1236 453 124, www.teledyne-europe.com.***
***Booth 407/506*** ***RS 262***

## Design Software



Concerto v6, the new version of its integrated software for RF and microwave design, has just been released. The suite includes Conforming FDTD analysis, Moment Method analysis and Finite Element analysis modules, all running within a single environment. The optimization module has been enhanced and a 64-bit Linux version included. "Concerto Essential" is also available as a low cost entry-level option. Concerto is now integrated into AWR's Microwave Office® circuit design platform. The link allows users of Microwave Office to obtain accurate FDTD calculations of component S-parameters and radiation patterns, simply by calling Concerto from within the Office environment.

***Vector Fields Inc., Aurora, IL (630) 851-1734, www.vectorfields.com.***
***Booth 548*** ***RS 265***

# ERRATUM

In "CPW Transmission Insertion Loss on Si and SOI Substrates," a technical feature that appeared in the November 2005 issue of *Microwave Journal*, the authors were not correctly listed with the article. The article byline should read: Suhua Luo, Weiguo Shan, Weili Liu, Miao Zhang, Chenglu Lin and Xiaowei Sun, Shanghai Institute of Micro-System & Information Technology, Chinese Academy of Science, Shanghai 200050, China.





# NEW LITERATURE

## APPLICATION NOTE

This free power limiter application note, "Protect your Investment with Agilent Power Limiters," features the importance of power limiters and how limiters can help protect their sensitive test equipment and components. This paper discusses limiter basics including applications and characteristics for maximum protection and the company's latest limiter technologies. To download a copy, visit http://cp.literature.agilent.com/litweb/pdf/5989-4880EN.pdf.

***Agilent Technologies Inc.,***
***Palo Alto, CA (800) 829-4444,***
***www.agilent.com.***

**RS No. 200**

## PRODUCT DATA SHEET


This data sheet provides detailed information on the company's precision noise measurement system, the AU3000 series. This system provides digitally-controlled, electronic and mechanical tuner-based test systems for small-signal characterization of semiconductor devices for the RF, microwave and millimeter-wave industry.

***Auriga Measurement Systems LLC,***
***Lowell, MA (978) 441-1117,***
***www.auriga-ms.com.***

**RS No. 201**

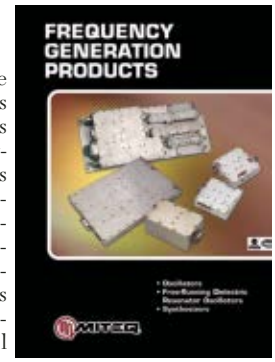
## COMPONENTS CATALOG


This 120-page catalog contains the company's coaxial cable assemblies, attenuators, adapters, power dividers, bias tees, coaxial switches, isolators/circulators, and adapters and attenuator testing kits. This catalog is handy for design engineers and buyers who are looking for product specifications and pricing for new development.

***Electronika International Inc.,***
***Cleveland, OH (440) 743-7034,***
***www.electronikainc.com.***

**RS No. 202**

## PRODUCT CATALOG




This 104-page catalog features the company's frequency generation products that include oscillators, free-running dielectric resonator oscillators and its full line of synthesizers. Full electrical specifications, outline drawings, block diagrams as well as typical phase noise charts are featured.

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

**RS No. 203**

## FILTER DATA SHEET

This data sheet highlights the company's newest filter products for use in microwave applications. These products include high performance, low profile, flat pack combline filters suitable for both military and commercial markets. The data sheet is available for download on the company's site or contact the company for a hard copy.

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

**RS No. 204**

## POWER AMPLIFIERS DATA SHEET


This data sheet provides detailed information on the company's 10 to 20 W Ku-band power amplifiers, the MPC1-1220 series. This series is ideal for SATCOM systems serving military and commercial airborne and mobile platforms. A product photograph, description, performance features, electrical and mechanical specifications, and outline drawings are also provided.

***Sophia Wireless Inc.,***
***Chantilly, VA (703) 961-9573,***
***www.sophiawireless.com.***

**RS No. 205**


# The 2006 IEEE International Conference on Ultra-Wideband

Will be held at the Westin Hotel in Waltham, Massachusetts, USA, from 24 – 27 September 2006. This conference provides a forum for the latest UWB systems, technologies, and applications in both microwave and millimeter-wave bands. This conference is a continuation of a series of international UWB conferences held in Baltimore (2002), Reston-VA (2003), Oulu (2004), Kyoto (2004), and Zurich (2005).

IEEE

**General Chair:** Andreas F. Molisch *Mitsubishi Electric Res. Labs (also at Lund University-Sweden)*

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## Preliminary Technical Program

| Day | Time | Session | Title |
|---|---|---|---|
| Monday 25-Sep | 13:00-14:50 | M3A | Acquisition/Synchronization |
| | | M3B | Coding/Modulation |
| | | M3C | UWB-Impulse Radio I |
| | 15:10-17:00 | M4A | UWB Signal Generation |
| | | M4B | Coding/Modulation II |
| | | M4C | UWB-Impulse Radio II |
| Tuesday | 8:30-9:30 | T1A | Plenary Session I |
| 26-Sep | 9:50-12:00 | T2A | Transceiver Design I |
| | | T2B | Channel Modeling |
| | | T2C | UWB-OFDM |
| | 13:00-14:50 | T3A | Panel |
| | 15:10-17:00 | T4A | Transceiver Design II |
| | | T4B | Transmitted Reference |
| | | T4C | Diversity |
| Wednesday | 8:30-9:30 | W1A | Plenary Session II |
| 27-Sep | 9:50-12:00 | W2A | Networks and Applications |
| | | W2B | Coexistence I |
| | | W2C | Antennas |
| | 13:00-14:50 | W3A | Circuits I |
| | | W3B | Coexistence II |
| | | W3C | Positioning/Localization I |
| | 15:10-17:00 | W4A | Circuits II |
| | | W4B | Special Topics |
| | | W4C | Positioning/Localization II |

*The social program includes a dinner cruise aboard the "**Spirit of Boston**" on Tuesday evening.*

## Plenary Speakers

**Plenary I:** Robert A. Scholtz, *Recent Results and Challenges in Ultra-Wide Bandwidth Radio Systems*

**Plenary II:** Vincent Poor, *Energy and Bandwidth in Wideband Systems*

## Scheduled Workshops

| | |
|---|---|
| **WS1** | "The Art and Science of UWB Antennas", HansSchantz |
| **WS2** | "Ultra-Wideband Wireless Communications: From Conceptto Reality", Georgios B. Giannakis, Liuqing Yang |
| **WS3** | "Commercializing UWB for Mobile Applications", Matt Wellborn |
| **WS4** | "Tutorial for IEEE 802.15.4a and Related Research Activities", Dong Ha |
| **WS5** | "Signal Processing for Transmitted-Reference UWB Systems", Klaus Witrisal et al. |

Please go to our website at:
**http://www.ICUWB2006.org**
for updated information on the technical program, workshop schedule, registration information, social program and visitors information for the Boston area.

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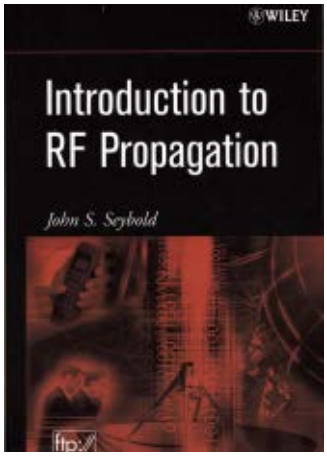
## Introduction to RF Propagation

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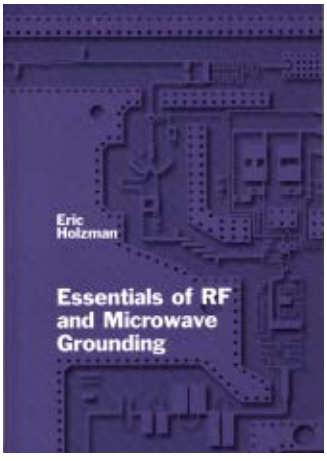
With the rapid expansion of wireless consumer products, there has been a considerable increase in the need for radio-frequency (RF) planning, link planning and propagation modeling. This book serves as an introduction to RF propagation and the associated modeling. In Chapter 1, the introduction, frequency designations, modes of propagation, and model selection and application are described. Chapter 2 provides a brief review of electromagnetic theory. While not exhaustive, it provides sufficient background and review for understanding the material in later chapters. Chapter 3 covers antenna fundamentals. Chapter 4 treats the basics of communication systems analysis. Chapter 5 provides a general overview of radar operation, primarily from the RF propagation standpoint. Many communication systems rely on RF propagation through the atmosphere. Thus, modeling atmospheric effects on RF propagation is an important element of system design and performance prediction. This is the subject of Chapter 6. Chapter 7 offers near-earth propagation models. Chapter 8 discusses fading due to shadowing, blockage and multipath caused by terrain features. Chapter 9 presents some statistical (site-general) models for indoor propagation, which is considerably different from the typical outdoor environment and in many ways more hostile. Chapter 10 provides the details of two well-known models for rain attenuation for microwave and millimeter-wave signals. In Chapter 11, many of the channel impairments that have been previously discussed are revisited and it is shown how they are applied to satellite communication links. Chapter 12 discusses the FCC limits and its guidelines for computation of the effects of prolonged exposure to low density electromagnetic waves.

## Essentials of RF and Microwave Grounding

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For RF and microwave engineers, the designers of high frequency electrical circuits and antennas, proper grounding means much more than safety. The rapidly alternating currents in microwave circuits also flow on conductors but the circuits are no longer strictly closed. One circuit's currents may transmit energy to the currents on another, physically removed circuit. If the high frequency grounding of these circuits is not properly designed, they may malfunction and interfere with each other. This book offers a comprehensive understanding of the proper grounding techniques to use in high frequency design projects. Chapter 1 gives an overview of the topics covered in the book and introduces low frequency grounding, starting with simple lumped circuit examples. Chapter 2 reviews electromagnetic theory, starting with Coulomb's postulate for the forces between two charges and progressing quickly to steady state, time harmonic fields. Chapter 3 discusses a variety of conductor-based transmission lines, including coaxial, microstrip and waveguide. The flow of currents on these transmission lines is examined. Chapter 4 discusses grounding and transitions between different types of transmission lines. Chapter 5 looks at grounding in active microwave component design. Components constructed from diodes, including switches and mixers, are examined and then a significant portion of the chapter is devoted to microwave FETs. The last section of the chapter covers grounding of active devices on printed circuit boards. Antennas and ground planes are the topic of Chapter 6. As with microwave circuits, the currents flowing on antennas are what matters. Unlike circuits, however, antennas are designed so these currents radiate as efficiently as possible.

# Microwave Journal® proudly announces the William Bazzy fellowship program

Named in honor of William Bazzy, founder of Microwave Journal® the fellowship is open to graduate students and working engineers to promote continued study, research and advancement in the field of RF and microwave engineering. A $5,000 fellowship will be awarded each spring.

An independent academic panel will select a fellowship recipient based on a written proposal of studies to be done, submitted by the applicant.

For complete fellowship details and application form visit the Microwave Journal® website www.mwjournal.com.

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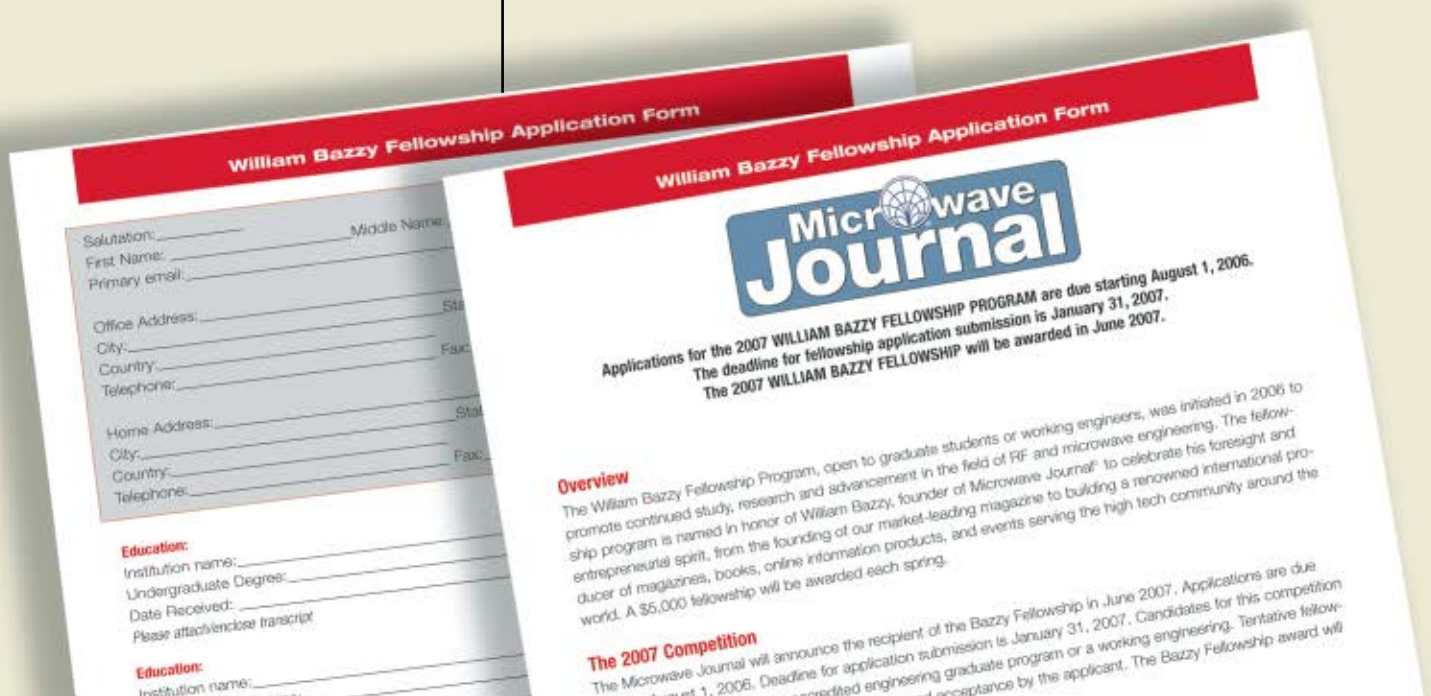

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*Phase Noise: SSB at 10kHz offset, dBc/Hz.

***U.S. Patent Number 6,790,049***

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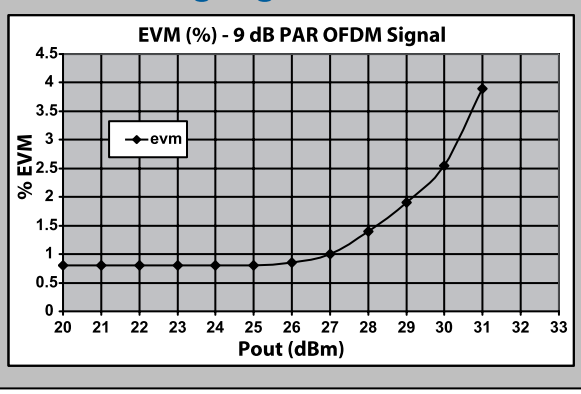


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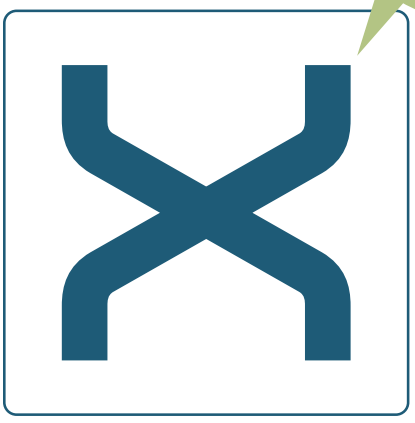

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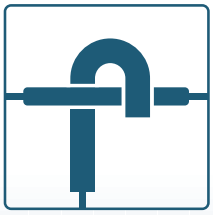
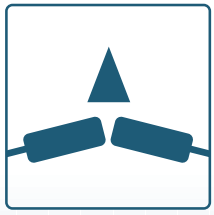
| QH7700 | 100-500 | 350 | 0.3 | 1.15:1 | 25 | 0.4 | 3 | 4.3 x 1.5 x 0.27 |
| QH7349 | 100-1000 | 50 | 0.6 | 1.30:1 | 20 | 0.75 | 5 | 4.6 x 1.7 x 0.3 |
| QH7469 | 200-2000 | 50 | 0.35 | 1.40:1 | 20 | 0.8 | 8 | 3.2 x 1.15 x 0.3 |
| QH7644 | 500-2500 | 50+ | 0.5 | 1.35:1 | 18 | 0.6 | 5 | 1.65 x 1.1 x 0.09 |
| QH7661 | 500-2800 | 50+ | 0.5 | 1.35:1 | 18 | 0.6 | 5 | 1.65 x 1.1 x 0.09 |
| QH7593 | 500-2800 | 200 | 0.3 | 1.35:1 | 18 | 0.4 | 5 | 2.2 x 1.9 x 0.45 |
| QH7100 | 500-2800 | 350 | 0.3 | 1.35:1 | 18 | 0.4 | 5 | 2.6 x 2.3 x 0.85 |
| QH7622 | 500-3000 | 50+ | 0.5 | 1.35:1 | 18 | 0.6 | 5 | 1.65 x 1.1 x 0.09 |
| QH7655 | 1000-3000 | 100 | 0.4 | 1.35:1 | 18 | 0.4 | 5 | 1.35 x 0.65 x 0.09 |

# Wide bandwidth, HIGH POWER DEVICES

Unsurpassed quality + on-time delivery, is the Werlatone promise



COUPLERS



COMBINERS

DIVIDERS

HYBRIDS