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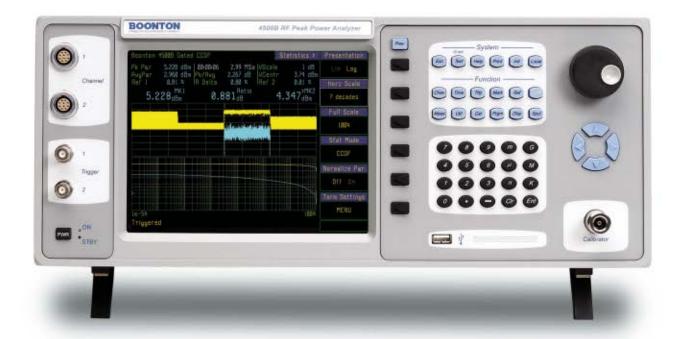
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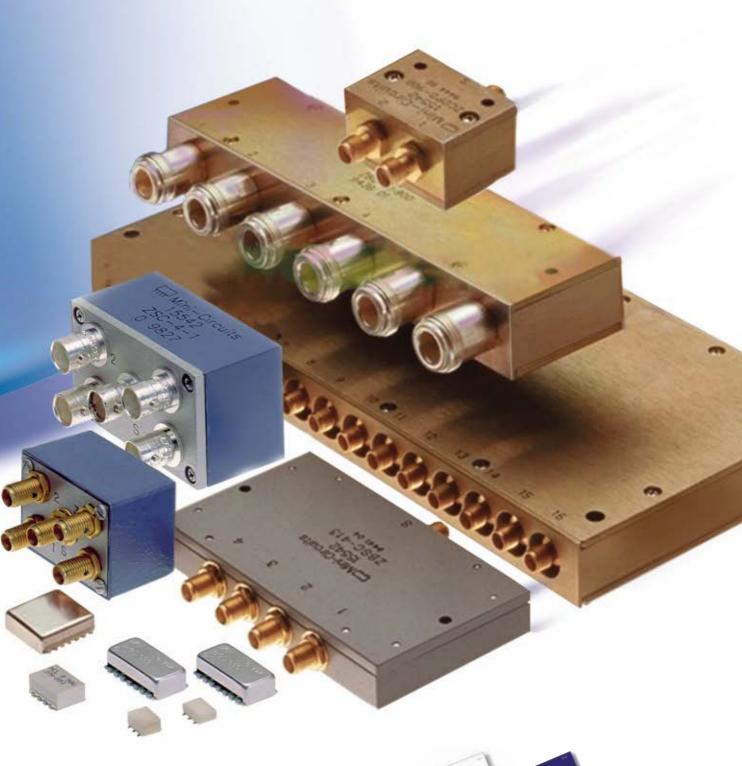


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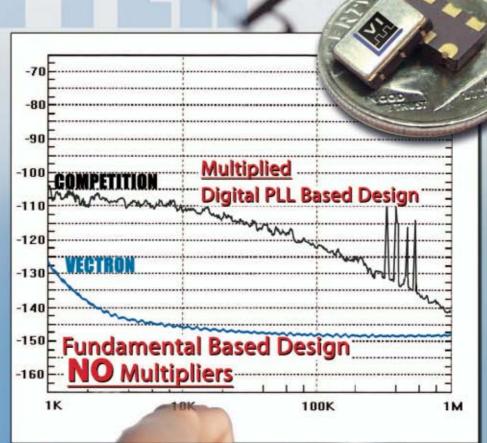
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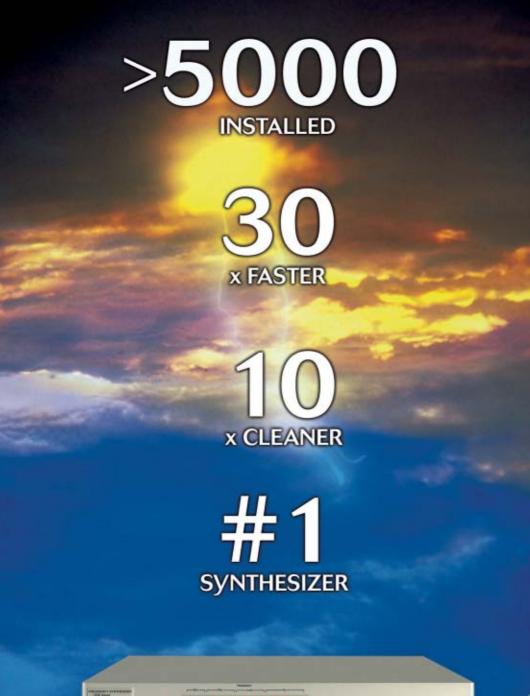
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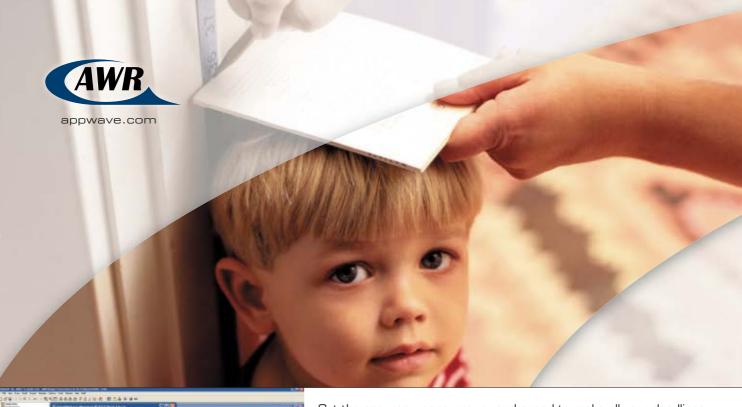
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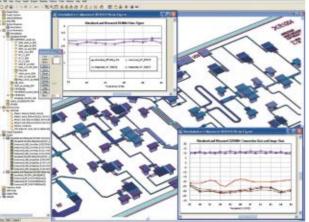
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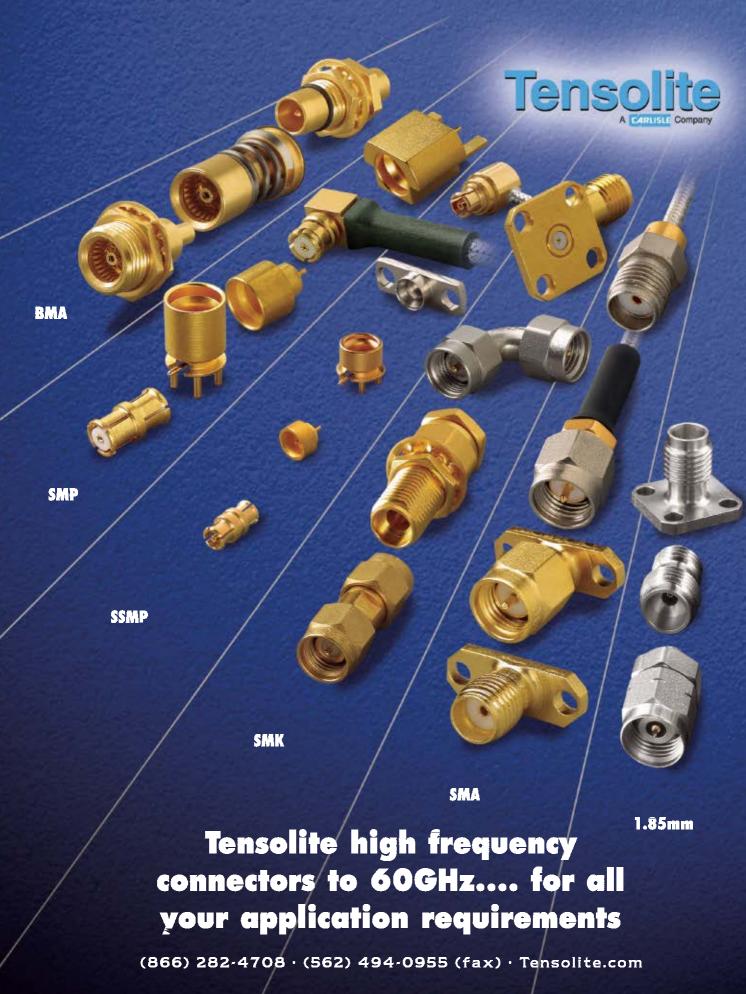
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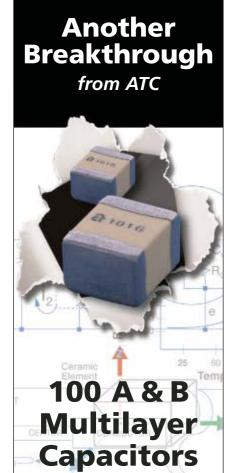
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## 2006... THE YEAR OF THE DOG

t seems only fitting to recognize the Chinese New Year, with all of the attention being paid these days to the Asian market. Greater China has evolved into the most dynamic market in the world, with vast implications for the microwave industry. With that in mind, Microwave Journal will publish a "Special Report" in the March issue, written by market expert Jack Daniels of EastBridge Partners, LLC. Jack will discuss the current state of the microwave industry in China and present options for entry into Greater China. Watch for this and other timely articles focused on emerging markets and technologies this year. This month, industry icon Eli Brookner of Raytheon presents an overview of phased arrays and radars in the "Cover Story," as we continue our monthly features addressing the current state and future trends of specific product sectors. If you were unable to attend last October's European Microwave Week event, check out European Editor Richard Mumford's recap in this month's "Special Report."

I'm pleased to announce the launch of the completely redesigned www.mwjournal. com, to debut next month. We've taken the hundreds of articles contained in our archives and added lots of new and unique resources to create a dynamic portal to the RF/microwave industry. You'll find daily news updates, complete event listings and links, and a directory of manufacturers that provides easy access to company and product information from over 1000 manufacturers. New features include the "Custom Cable Assembler" and "RF to Light 100" index, resources unique to our web site. The "Ask Harlan" column will be expanded and will soon be featured on-line and in print. Readers will be invited to submit

answers to the featured "Question of the Month," with the chosen answer appearing in *Microwave Journal* and all of the answers appearing on our web site, along with editor Harlan Howe's answers and insight.

The *Microwave Flash* e-mail newsletter has a new look and new features this year as well. You'll find the latest news, product announcements and industry events delivered to you weekly. If you're not already a subscriber, you can sign-up on our web site. You can also sign-up for our new eNewsletter, the *RF to Light 100*. Produced by industry veteran Gunter Vorlop, this feature delivers financial data and analysis of 100 of the publicly traded companies in the RF to lightwave industry, broken down into seven major sectors and updated weekly. I think you'll find it to be a valuable resource.

Last year, we introduced the digital edition of *Microwave Journal*. Recently, we upgraded to a format that allows users to access the magazine instantly on-line, with no download required. You can move the issue to your computer for off-line reading as well.

The digital edition allows you to link to authors and advertisers, e-mail articles to colleagues, print articles and receive each issue much faster. You can check it out at www.mwjournal-digital.com.

You'll also find some subtle changes within these pages, as we are always looking for ways to improve your reading experience. As always, I welcome your comments at csheffres@mwjournal.com.

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

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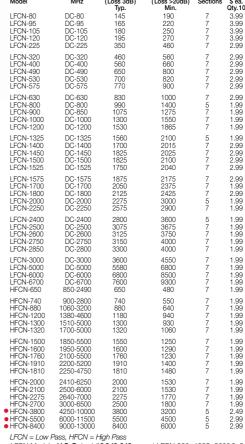
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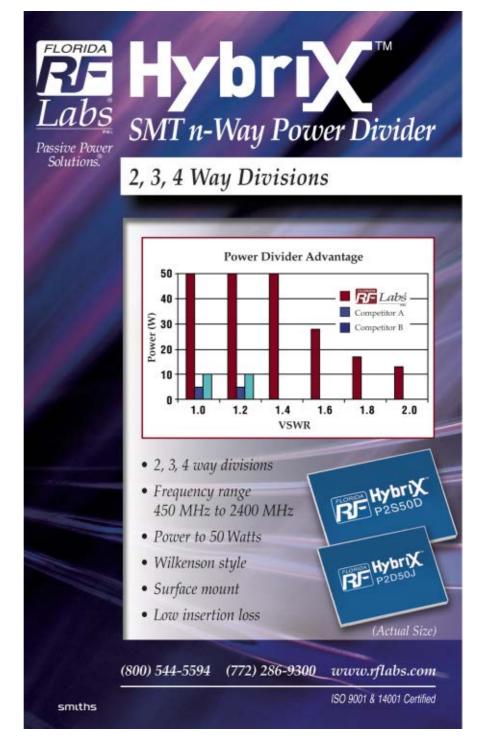
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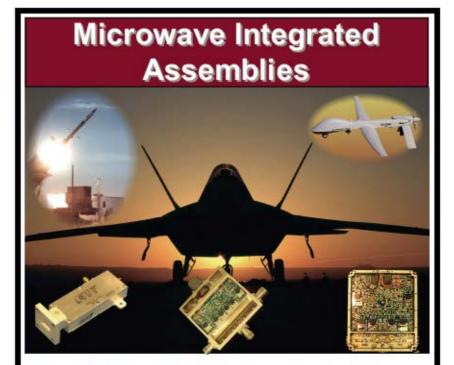
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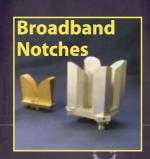
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#### PHASED ARRAYS AND RADARS — PAST, PRESENT AND FUTURE

¶his is a survey article summarizing the recent developments and future trends in passive, active, bipolar and monolithic microwave integrated circuitry (MMIC) phased arrays for ground, ship, air and space applications. Covered is the DD(X) ship radar suite; THAAD (formerly GBR); European COBRA; Israel BMD radar antennas; Dutch shipboard APAR; airborne US F-22, JSF and F-18 radars, European AMSAR, Šwedish AESA, Japan FSX and Israel Phalcon; Iridium passive phased arrays having (66 satellites in orbit for a total of 198 anten-

nas) and Globalstar MMIC space-borne active array systems (these last two are for communications, but the technology is the same as used by radar systems. In fact, the IRIDIUM T/R module technology derives from technology developed for a space-based radar); Thales (formerly Thomson-CSF) 4" MMIC wafer, 94 GHz seeker antenna; digital beamforming; ferroelectric row-column scanning; optical electronic scanning for communications and radar; the MMIC C- to Ku-band advanced shared aperture program (ASAP) and AMRFS antenna systems for shared use for communications, radar, electronics countermeasures (ECM) and electronic support measures (ESM); and the continuous transverse stub (CTS) voltage-variable dielectric (VVD) antenna

#### **ACCOMPLISHMENTS OVER THE LAST** TWO AND A HALF DECADES

Phased arrays have come a long way in the last three decades. This is illustrated by the many tube passive arrays and solid-state active arrays, which use discrete and MMIC technologies that have been deployed or are under development. 1-24,82-84,86 Figures 1 and

AEGIS (SPY-1) (234)

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Fig. 1 Examples of US large productions.



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Fig. 2 Examples of passive phased arrays from around the world.

2 show passive phased arrays, the first generation of phased arrays. Figure 3 shows Rotman lens arrays. Fig-

ure 4 shows active solid-state arrays using discrete components, the second generation. Figures 5 and 6 are

for phased arrays using microwave analog integrated circuits (MMIC), the third generation. The numbers manufactured are shown in parentheses in the figures. Note that in some cases, very large numbers have been produced, even for MMIC active phased arrays (see **Table 1**). Also, one sees that phased arrays are being developed around the world. Included are the new L-band GEC-Marconi S185OM (SMARTELLO), which will provide very long range search for the SAMPSON radar on the Royal Navy Type 45 anti-air warfare (AAW) destroyer and the new AMS L-band RAT 31DL.86 The SMARTELLO uses the SMART-L antenna and elements of the Martello. The Iridium satellite system has been deployed; it consists of a constellation of 66 satellites. It was a great technological success but unfortunately not a financial one. 14 It is still in operation, however. In fact, three replacement satellites were launched in 2002. Figure 7 shows additional phased arrays that have recently come under development, for



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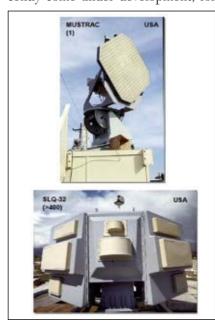
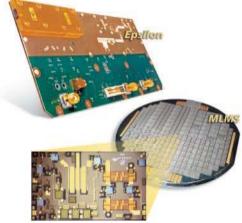


Fig. 3 Examples of ROTMAN lens arrays.

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Fig. 4 Examples of active arrays using discrete components.

which the technology is not specified. Included are the US Army's joint land attack cruise missile defense elevated netted sensors system (JLENS), con-

the total Microwave Solution > DC - 50 GHz > Custom Designs > Multifunction RF Modules > Components Filters • Amplifiers Switches • Multipliers • T/R Modules • Oscillators > MMICs > Low-Cost Manufacturing One company... multiple technologies... optimum solutions. REMEC Defense & Space 858.560.1301 | sales@remecrds.com | www.cheltonmicrowave.com sisting of a long range 3-D surveillance radar and a high frequency precision tracking and illumination radar deployed in an aerostat; the medium extended air defense system (MEADS) UHF surveillance radar; the US Army's multi-mission radar (MMR): UK/US airborne stand-off radar (ASTOR), the UK equivalent of the US joint STARS (JSTARS), and the US Marine Corps affordable ground-based radar (AGBR) and multiple role radar system (MRRS). Figures 8 and 9 give the state-ofthe-art of GaAs MMIC power amplifiers and of GaAs and InP low noise amplifiers (LNA).85 The People's Republic of China has come a long way in a very short time in the development of phased arrays — passive, active, over-the-horizon, dual-band, wide-band, ultra-low sidelobe, synthetic-aperture, adaptive, digitalbeamforming, super-resolution and phase only null steering.<sup>76</sup> The question addressed now is what does the future hold?

#### DEVELOPMENT OF MMIC ACTIVE PHASED ARRAYS

With the recent awards of production and development contracts for MMIC active phased array contracts, such as for three THAAD EDM (engineering development model) radars, COBRA radars, SAMPSON radars, sea-based test XBR radars, forward-based BMDs radars, MEADS radars, air traffic navigation, integration and coordination system (ATNAVICS) radars, four-faced active phased-array radar (APAR) system, the new B-2 radar, multi-platform radar technology insertion program (MP-RTIP) on E-10A (upgrade of the Joint STARS), MP-RTP on Global Hawk, F-15C (AN/APG-63(V), 25 already in service), F-16, F/A-18, F/A-22 and F-35 joint strike fighter (JSF) airborne radars, the planned development

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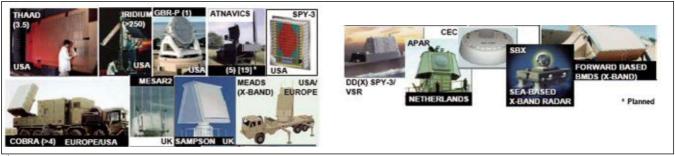
Model	Frequency Range (MHz)	Modulation Type	P1dB (dBm)	Power Gain [d8]	Channel Power @-45 dBc ACP	Voltage (V)	Operating Current (mA)	PAE* (%)	Package Size
AP501	1930-1990	15-95A	+36	30.5	+30.5	12	520	16	29 x 13 x 4 mm
AP502	2110-2170	W-CDMA	+36	28	+27	12	410	10	29 x 13 x 4 mm
AP503	1805-1880	COMAZOOO	+36	31.5	+30.5	12	460	17.5	29 x 13 x 4 mm
AP504	1710-1785	CDMAZOOO	+36	33	+30.5	12	460	17.5	29 x 13 x 4 mm

All parameters are shown for their performance at the specified output channel power level with the specified signal modulation type.

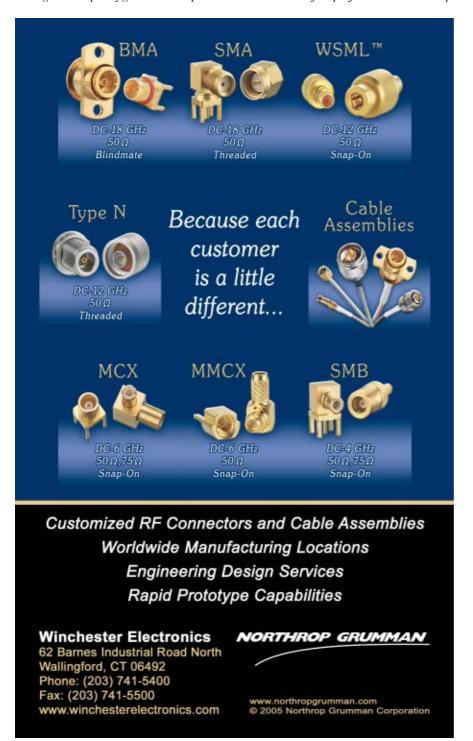


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lacksquare Fig.  $5\,$  Examples of ground and shipboard MMIC active arrays deployed and under development.

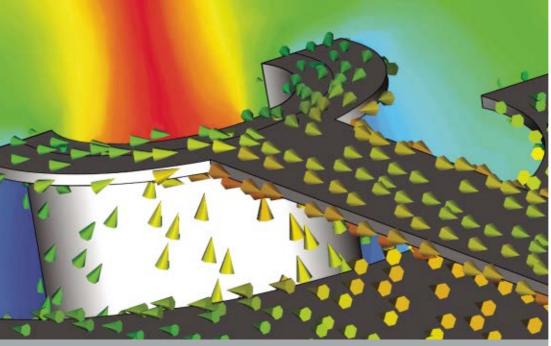


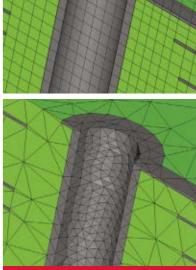
contracts for the new US DD(X) ship and SPY-3/VSR radar suite, the future looks very good for MMIC radars. 79,80,83 The new X-band SPY-3 under development for the DD(X) ship, the US Navy's first active radar, is planned to be used for the detection, tracking and illumination of low flying, anti-ship, cruise missiles and is expected to consist of a threefaced radar.83 When not supporting engagement operations, it will perform horizon search, surface search and periscope detection.<sup>83</sup> The cooperative engagement capability (CEC) is a Navy ship and communications array antenna. Figures 10 and 11 show space-based radar and digital beamforming phased-array systems that have been deployed or are under development.

#### RESEARCH AND DEVELOPMENT WORK FOR FUTURE PHASED-ARRAY SYSTEMS

#### Clutter Rejection for an Airborne System (STAP and DPCA)

To cope with ground clutter and sidelobe jamming for airborne radar, extensive work is ongoing toward the development of an airborne phased array using space-time adaptive processing (STAP).<sup>25,26</sup> STAP is a general form of displaced phase center antenna (DPCA) processing. STAP had been demonstrated several years ago on a modified E2-C system by NRL.<sup>27,28</sup> More recently, a flight demonstration STAP provided 52 to 69 dB of sidelobe clutter cancellation relative to the main beam clutter.29 This system used an array mounted on the side of an aircraft. The antenna had 11 degrees of freedom in azimuth and two in elevation, for a total of 22. Before STAP, the antenna RMS sidelobe level was -30 dBi; with STAP, it was -45 dBi.





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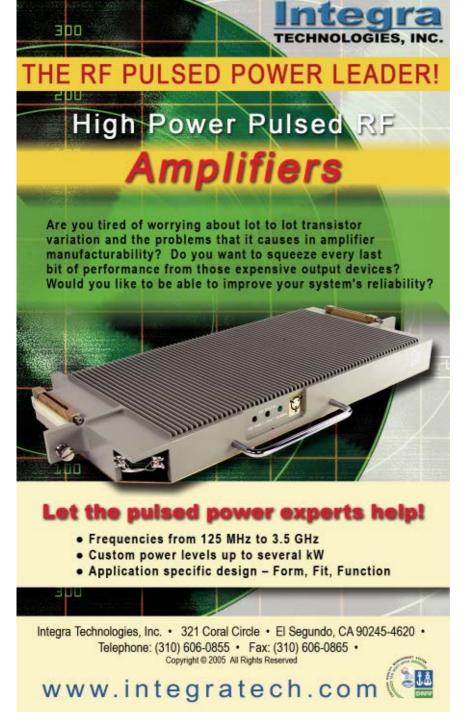


CHANGING THE STANDARDS.

#### C- to Ku-band Multi-user Advanced Shared Aperture Program (ASAP) MMIC Array and Dual-band AMRFS and RECAP Arrays

The COBRA DANE radar system has a 16 percent bandwidth and the Rotman lens multi-beam array systems have a 2.5 to 1 frequency bandwidth. Technology had been carried out to develop an active MMIC phase-phase steered array that has a greater than 2 to 1 frequency band-

width and at the same time is shared by multiple users. Specifically, the Naval Air Weapons Center (NAWC) and Texas Instruments (TI, now part of Raytheon) were developing a broadband array having continuous coverage from C- through Ku-band that would share the functions of radar, passive electronic support measures (ESM), active electronic counter measures (ECM) and communications.<sup>30</sup> To achieve this wide bandwidth, a flared notch-radiating element was used. Cross notches were used so that horizontal, vertical or circular polarization could be obtained. They built a solid-state T/R module that provides coverage over this wide band from C- to Ku-band continuously. The module had a power output of 2 to 4 W per element, a noise figure between 6.5 and 9 dB, and power efficiency between 5.5 and 10 percent, over the band. A 10 by 10-element array, having eight active T/R modules, was built for test purposes. A typical full-up array would be approximately 29" wide by 13" high. With this type of array, it would be ultimately possible to use simultaneously part of the array as radar, part of the array for ESM, part for ECM and part for communica-





▲ Fig. 6 Examples of airborne MMIC active arrays deployed and under development.



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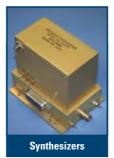




TABLE I  EXAMPLES OF RADAR PHASED ARRAYS HAVING LARGE PRODUCTIONS							
System	Frequency Band	Number Manufactured	Number of Phase Shifters/Array	Total Number of Elements Manufactured	Manufacturer		
AN/TPN-25	X	18	824	14,850	Raytheon		
AN/GPN-22	X	60	443	26,580	Raytheon		
COBRA DANE	L	1	15,360 (34,769 Els.)	15,360 (34,769 Els.)	Raytheon		
PAVE PAWS	UHF	4	1,792/face (2,677 Els.)	14,336 (21,416 Els.)	Raytheon		
BMEWS UPGRADE	UHF	2	2,560/face (3,584 Els./face)	12,800 (17,920 Els.)	Raytheon		
COBRA JUDY	-	1	12,288	12,288	Raytheon		
PATRIOT	С	173	5,000	1,730,000	Raytheon		
AEGIS (SPY-1)	S	234	4,000	936,000	Lockheed-Martin		
B-1	X	100	1,526	152,600	Northrop Grumman		
AN/TPQ-37	S	102	359	36,618	Raytheon		
AN/TPQ-36	X	243			Raytheon		
FLAP LID	X	> 100 (?)	10,000	> 2 million (?)	Russia		

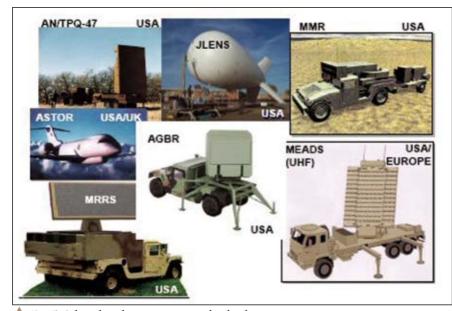


Fig. 7 Other phased-array systems under development.

tions. The parts used for each function would change dynamically, depending on the need. Also, these parts could be non-overlapping or overlapping, depending on the needs. Although the ASAP funding has ended, the shared aperture technology is now being pushed forward by the US Office of Naval Research (ONR) advanced multifunction radar frequency system (AMRFS) program<sup>71,78</sup> and the DARPA reconfigurable aperture program [RECAP] program. DERA of the UK had been developing a dual frequency array which would en-

able a single radar to use L-band for search and X-band for track, so as to avoid the use of a single compromise frequency for search and track.<sup>52</sup> Consideration is being given to the use of waveguide L-band radiating elements and dipole X-band elements.

#### Digital Beamforming and Its Potential

**Table 2** lists where digital beamforming (DBF) has been operationally used, some developmental systems that have been built, and its significant advantages. The first operational

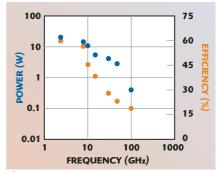


Fig. 8 State-of-the-art of GaAs MMIC
PAs.

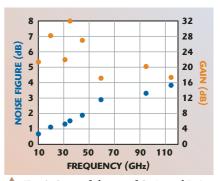


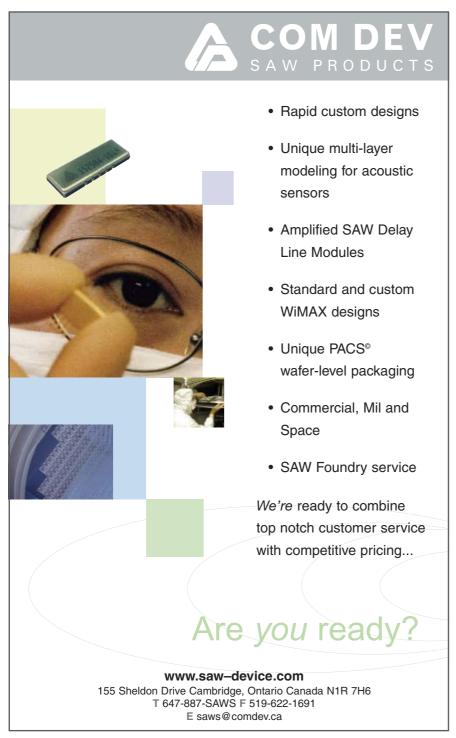
Fig. 9 State-of-the-art of GaAs and InP MMIC LNAs.

radars to use digital beamforming are the over-the-horizon (OTH) radars, specifically the GE OTH-B and Raytheon relocatable OTH radar (ROTHR). The ROTHR receive antenna is approximately 8500 feet long. More recently, Signaal used digital beamforming for their deployed 3-D stacked beam SMART-L and

#### FREQUENCY SYNTHESIZER HIGH SPEED DIRECT ANALOG Model: MW-15131MP-2-18-00 2.0-18.0 GHz Features • Low Spurious <-70 dBc • Harmonics - 50 dBc max. Noise Floor -140 dBc Phase-noise -105 dBc/Hz @ 1 KHz • Settling Time < 1 micro second Resolution 1 Hz • Phase and Frequency Coherent • FM Modulations Built-in Electrical Specifications 2.0 to 18.0 GHz **Frequency Range Frequency Step** 1 Hz **Settling Time** 1 microsec max **Output Power** +10 dBm min **Output Power Variation** ±3 dB typ. Internal Reference Frequency 100 MHz · Accuracy and Temp. Stability $\pm 0.1$ ppm (optional $\pm 0.01$ ppm) **External Reference** (Requirements) Frequency 100 MHz 7 dBm • Input Level Impedance 50 Ohm -70 dBc max. up to ±100 MHz from carrier **Spurious Harmonics** -50 dBc max. - 60 dBc/Hz max @ 10 Hz **Phase Noise** -90 dBc/Hz max @ 100 Hz -105 dBc/Hz max @ 1 KHz -120 dBc/Hz max @ 10 KHz -125 dBc/Hz max @ 100 KHz -130 dBc/Hz max @ 1 MHz -135 dBc/Hz max @ 10 MHz **Noise Floor** -140 dBc Wideband FM Modulation Modulation Frequency DC to 6 MHz Deviation ±250 MHz max. Modulation Rate 500 MHz / 1 usec Frequency Accuracy ±10 MHz • FM Chirp Phase: Coherence For steps of 1 MHz and above For steps below 1 MHz contact factory Frequency is Coherent Narrowband FM Modulation electronic systems ltd. Modulation Frequency ±50 MHz max Modulation Rate 100 MHz / 1 microsec Frequency Accuracy same as the reference Frequency Monitoring Output P out -20 dBc typical (relative to main output) Microwave Division Frequency Control BCD (41 bit+stb) AC Power 110 or 220 VAC / 47 -63 Hz



Fig. 10 Space-based phased-array systems.



SMART-S shipboard systems. Each row is down converted and pulse compressed with SAW lines and then analog-to-digital (A/D) converted with 12-bit, 20 MHz Analog Devices A/Ds. The signal is then modulated onto an optical signal and passed down through a fiber optic rotary joint to a digital beamformer where 14 beams are formed.<sup>31</sup>

A number of experimental DBF systems have been developed. One is the Rome Laboratory (Hanscom AFB, MA), 32 column linear array at C-band that can form 32 independent beams and uses a novel self-calibration system.<sup>32</sup> Rome Laboratories has also developed a fast digital beamformer that utilizes a systolic processor architecture<sup>77</sup> based on the quadratic residue number system (QRNS).<sup>32</sup> MICOM (US Army) built a 64-element feed that used DBF for a space-fed lens.33 The experimental British MESAR S-band system does digital beamforming at the sub-array level.<sup>34</sup> This experimental system has 16 sub-arrays and a total of 918 waveguide-radiating elements and 156 T/R solid-state modules. Roke Manor Research Ltd. of Britain has built an experimental 13-element array using digital beamforming on transmit as well as on receive. 35 This experimental system uses the Plessey SP2002 chip running at a 400 MHz rate as a digital waveform generator at every element. Doing digital beamforming on transmit allows one to put nulls in the direction of an ARM threat or where there is high clutter.

The National Defense Research Establishment of Sweden has built an experimental S-band antenna operating between 2.8 and 3.3 GHz, which does digital beamforming using a sampling rate of 25.8 MHz on a 19.35 MHz IF signal.<sup>23</sup> The advantage of using IF frequency sampling rather

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	Broad	lband L	Broadband Low Noise Amplifiers	Amplifier	S		
	0.1 – 6.0	28	±1.25	1.3*	+7	2.0:1	190
	4.0 - 8.0	30	+1.0	1.2	+10	1.8:1	150
	4.0 – 12.0	30	±1.5	1.5	+10	1.8:1	150
	2.0 – 18.0	6	⊕1.0	2.2	+2	2.5:1	09
AML0518L1601-LN	0.5 - 18.0	16	+1.0	2.7	<b>8</b> +	2.2:1	100
	0.1 - 26.5	22	±2.25	3.5*	<b>8</b> +	2.2:1	170
	12.0 – 26.5	33	±2.0	2.8	<b>8</b>	2.5:1	200
	Broadb	and Me	Broadband Medium Power Amplifiers	er Amplif	iers ——		
	0.01 - 6.0	21	±1.25	3.2*	+23*	2.0:1	480
	2.0 – 6.0	28	±2.5	9	+33	1.8:1	1500
	2.0 - 8.0	30	±2.0	5.5	+33	2.0:1	2000
	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	v Band	Narrow Band Low Noise Amplifiers	Amplifie	ırs —		
	2.8 – 3.1	28	±0.75	7.0	+10	1.8:1	150
	14.0 – 14.5	54	±0.75	1.5	+10	1.5:1	130
	17.0 – 18.0	24	±0.75	1.6	+10	1.8:1	150
ä	— Low Phase Noise Amplifiers	fiers –		— Pha	Phase noise (dBc/Hz) at offset	Bc/Hz) a	nt offset
	Frequency (GHz)	Gain (dB)	Output Power (dBm)	100Hz	1KHz	10KHz	100KHz
	8.5 - 11.0	6	17	-154	-159	-167	-170
	8.5 – 11.0	18	18	-152.5	-157.5	-165.5	-168
	8.5 – 11.0	15	28	-145.5	-153.5	-158.5	-164.5
	2.0 – 6.0	6	20	-150	-165	-165	-178
	2.0 – 6.0	7	15	-155	-160	-160	-175
-1	High	Dynan	High Dynamic Range Amplifiers	Amplifie	, S		
	Frequency (MHz)	Gain	P1dB (dBm) OIP3 (dBm)	OIP3 (dBm	) DC		
	2 – 32	(dB)	32	52	+28V @ 470mA	Jm A	
	20 – 500	23	28	53	+28V @ 700mA	)mA	
	20 - 2000	32	30	43	+15V @ 1100mA	0mA	

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DC Current(A) @ +12V		14	14	8.5	က	17	22	22	22		4	2	10	2	10	9	4	12	10			Height (in)	10.25	8.75	10.25	5.25	5.25	5.25	5.25	5.25	5.25
Gain (dB)	olifiers —	45	45	40	30	45	45	45	45	ers ——	35	30	38	30	38	35	35	40	40	ers —	í	(kW)	1.8	-	2	0.35	0.25	0.25	0.25	0.25	0.24
P1dB (dBm)	<b>Broadband Microwave Power Amplifiers</b>	41.5	42.5	38.5	29	41.5	41.5	42	41.5	Millimeter-Wave Power Amplifiers	33	56	36	26	36	33	29	35	35	High-Power Rack Mount Amplifiers	į	(dBm)	51.5	49	49.5	45	41.5	39	39	39	38
Psat (W)	Microwave	17.8	25	10	-	20	20	22	20	er-Wave Po	2.5	0.5	2	0.5	2	2.8	-	4	4	rer Rack M		(W)	170	100	110	40	20	10	10	10	ω
Psat (dBm)	<b>3roadband</b>	42.5	4	40	30	43	43	44	43	- Millimete	34	27	37	27	37	35	30	36	36	High-Pow		rsat (dBm)	52.5	20	50.5	46	43	40	40	40	39
Frequency (GHz)		1 - 4	2 - 4	2 - 6	2 - 18	4 - 8	6 - 18	8 - 12	12 - 18		18 - 26	18 - 40	26 - 32	26 - 40	26.5 - 30.5	27 - 32	30 - 40	32 - 36	36 - 40		ı	rrequency (GHz)	7.1 - 7.7	9 - 10.5	14 - 14.5	14 - 16	18 - 20	23 - 26	26.5 - 30.5	32 - 36	36 - 40
Model		L0104-43	L0204-44	L0206-40	L0218-30	L0408-43	L0618-43	L0812-44	L1218-43		L1826-34	L1840-27	L2632-37	L2640-27	L2630-37	L2732-35	L3040-30	L3236-36	L3640-36			Model	C071077-52	C090105-50	C140145-50	C1416-46	C1820-43	C2326-40	C2630-40	C3236-40	C3640-39



\*Above 500MHz.

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than base band sampling is that one does not have to worry about the imbalance between the two I and Q channels, or the DC offset. They demonstrated that, by using digital beamforming, they could compensate for amplitude and phase variations that occur from element to element, across angle and across the frequency band. Via a calibration, they were able to reduce an element-to-element gain variation over angle, due to mu-

tual coupling, from  $\pm 1$  dB to approximately  $\pm 0.1$  dB. Using equalization, they were also able to reduce a  $\pm 0.5$  dB variation in the gain over the 5 MHz bandwidth to less than  $\pm 0.05$  dB. With this calibration and equalization, they were able to demonstrate peak sidelobes 47 dB down, over a 5 MHz bandwidth. A 50 dB Chebyshev weighting was used. The RMS of the error sidelobes was down 65 dB from the peak near bore-

sight.<sup>63</sup> They demonstrated that the calibration was maintained fairly well over a period of two weeks. This work demonstrates the potential advantage offered by digital beamforming with respect to obtaining ultra-low antenna sidelobes. These results were not achieved in real time in the field, although that is ultimately the goal.

MIT Lincoln Laboratory developed the technology for an all-digital radar receiver for airborne surveillance array radar like that of the UHF E-2C.43 They are A/D sampling directly at UHF (~430 MHz) using a Rockwell 8-bit, 3 Gbps A/D running at room temperature. Three stages of down conversion are done digitally and because the A/D quantization noise is filtered, the effective number of bits of the A/D is increased. For example, if the signal bandwidth is only 5 MHz, the increase in signal-tonoise ratio is 3 GHz/2 (5 MHz) = 25dB, so the increase in the number of

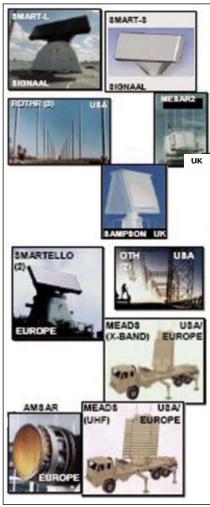


Fig. 11 Phased arrays that use digital beamforming.



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effective bits is 25 dB divided by 6 dB/bit or 4.2 bits to yield 12 bits total. The whole digital receiver is on an 8" by 8" card that uses three 0.6 µm chips. In the future these three chips could be replaced by a single 0.35 µm CMOS chip.

The Naval Research Laboratory (NRL), MIT Lincoln Laboratory and NSWC are jointly developing an Lband active array which has an A/D converter at every element. 64,65,81

Using digital beamforming, NRL demonstrated the ability to obtain a constrained beamwidth with frequency, while at the same time achieving low sidelobes over specified angles and frequency bands.66

MIT Lincoln Laboratory had been developing a high performance, low power signal processor to do digital beamforming and signal processing for a notional X-band Discoverer II space-based radar.67,68 This notional

version of the system did ground moving target indication (GMTI) and synthetic aperture radar (SAR) mapping. Its antenna consisted of 12 subarrays and 4 SLCs. The signal bandwidth was assumed to be 180 MHz. For this system, it is necessary to do the signal processing on-board and in real time, because telemetering the signal down would require too high a data rate -35 Gbps, if a 12-bit A/D is assumed — well beyond the present state-of-the-art. The on-board signal processor must do digital beamforming, pulse compression, Doppler processing, STAP and SLC. To do this on-board and in real time requires a signal processor capable of 1100 GOPS (1.1 TERAOP). Lincoln Laboratory has shown that it is feasible to do the processing on board using a systolic array type architecture having a volume less than one seventh of a cubic foot, and weighing less than 13 kg with a power consumption less than 55 W. With the digital processing field being moved forward rapidly by the commercial world, by the year 2016 it is expected that one 9U 16" by 14.5" board would provide a throughput of 600 GFLOPS (floating OPS). It would consist of 64 chips, each providing 10 GFLOPS use a 0.07 µm technology and have a 1.25 GHz clock. Texas Instruments (TI) road map, for its TMS320 digital signal processor (DSP), indicates that by the year 2010 they expect to be able to do 3 trillion, 8-bit OPS (3 trillion instructions per second or 3 TIPS), on a single TMS320 chip.69 With 32bit fixed-point operations, this chip would do 0.75 TIPS. Assuming 10 percent efficiency, 15 chips would do the notional Discover II processing. Such processing capability could help make the experimental Swedish ultra-low sidelobe antenna and airborne STAP array feasible.

# **Row-column Steered Arrays**

The Naval Research Laboratory (NRL) had been developing two rowcolumn array steering techniques, which have the potential for low cost two-dimensional steered arrays.<sup>36,37</sup> The first technique, the one closest to possible deployment, involves using two arrays back-to-back. The first array steers the beam in azimuth, the second in elevation. The first array consists of columns of slotted wave-



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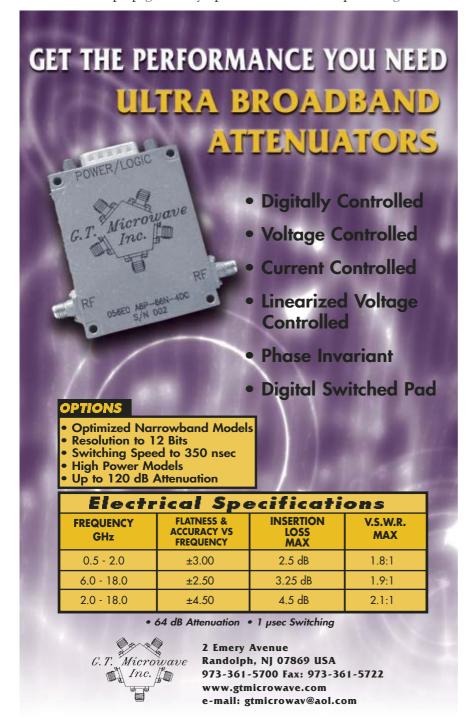
guides, with each column having at its input one ferrite phase shifter to provide azimuth scanning. The second array is a RADANT lens array, consisting of parallel horizontal conducting plates between which are connected many diodes. The velocity of propagation of the electromagnetic signal passing through a pair of parallel plates of the array depends on the number of diodes that are on or off in the direction of propagation. By ap-

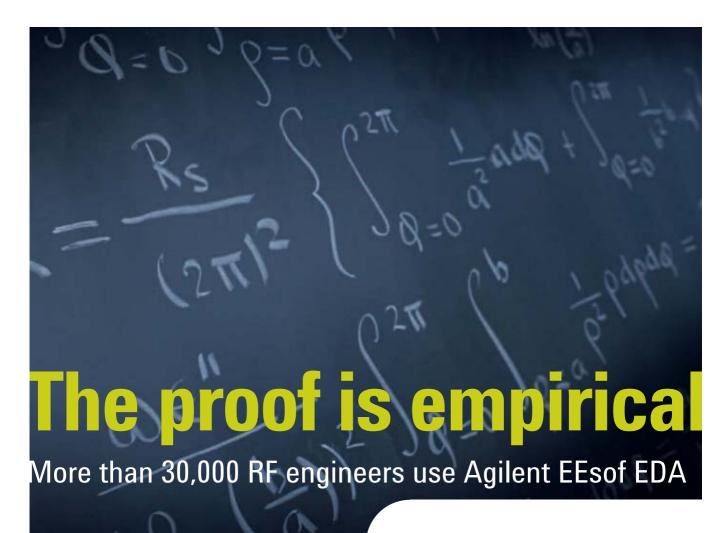
propriately varying this number, as one goes from one pair of plates to the next in the vertical direction, one creates a gradient on the signal leaving the lens in the vertical direction so as to steer the beam in elevation. The estimated production cost of the hybrid row-column steered array is \$3 million. It is possible to use two RADANT lenses to provide two-dimensional electronic scanning, one RADANT lens providing elevation

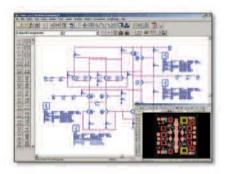
scan while the second provides azimuth scan. 38 Thales has developed such a RADANT antenna for the Dassault Aviation RAFALE multirole combat aircraft. 38

The second NRL row-column steered array involves using two ferroelectric lenses.<sup>37</sup> The first lens consists of columns of ferroelectric material placed between conducting plates. A DC voltage is applied across each pair of plates. The dielectric constant of the ferroelectric material depends on the DC voltage applied between the plates. As a result the phase of the electromagnetic signal passing through a ferroelectric column will depend on this DC voltage. Consequently, by applying an appropriate DC voltage across the ferroelectric columns, one can create a phase gradient in the horizontal direction for the signal leaving the first lens and thus scan the beam in azimuth. A second such lens, rotated 90°, would steer the beam in elevation. Considerable work is still necessary before a practical ferroelectric phased array is produced. This work has been shifted from NRL to industry.

The Raytheon Co. is developing a row-column steered array that employs phase shifters for steering in the H plane (see Figure 12) and a voltage variable dielectric (VVD) ceramic material used for a continuous transverse stub (CTS) antenna architecture for steering in the E plane.<sup>41</sup> Changing the voltage across the VVD changes its dielectric constant and, in turn, the velocity of propagation along the VVD. It provides for a lightweight, low cost, small thickness antenna. They are looking to apply this technology to aircraft radar antennas and commercial antennas. Engineers and scientists have been talking about achieving electronic scanning of lasers since the 1960s. Some thought this was a pipe dream, but these doubters have since been proven wrong. Raytheon<sup>40,57</sup> has demonstrated an electronically steered phased array for laser and optical beams. This array, which is carried around in a briefcase, represents a major breakthrough in the scanning of laser and optical beams. The scanning is achieved using a row-column scanning architecture similar to that of the ferroelectric scanner previous-









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TABLE II	
DIGITAL BEAMFORMIN	IG
Where Used:	Advantages:
• OTH-B (GE): I-D	Flexibility
<ul> <li>ROTHR (Raytheon): I-D</li> <li>SMART-L and SMART-S (SIGNAAL): I-D Stacked Beam Systems</li> </ul>	<ul><li>Antenna Weighting</li><li>Growth with Technology</li><li>Adaptive Processing</li></ul>
	Improved Performance
Developmental Systems:	- Ultra-Low Sidelobes
Rome Lab: 32 Columns	- Dynamic Range
32 Independent Beams	<ul> <li>Jammer and Clutter Suppression</li> </ul>
MICOM: Array Feed OF 64 Elements	- Reduced EMI
British MESAR: Subarray DBF	• Multibeams
British: DBF on Trans. and Rec. 13 EL	
Lincoln Lab. All-Digital UHF Receiver: 8 Bit 3 GSPS A/D	
AMSAR: Subarray DBF	

ly described, with liquid crystal used instead of the ferroelectric material. In production, the cost per phase shifter for an optical phased array is estimated to be pennies. 40,57

# Novel Electronically Steerable Plasma Mirror

NRL had been pursuing the development of a novel electronically steerable plasma mirror in order to provide electronic beam steering.<sup>39</sup> Here, a plasma sheet is rotated to steer the beam in azimuth and is electronically tilted to steer the beam in elevation. Switching to different initiation points in the cathode ro-

tates the plasma mirror. Tilting the magnetic field around the plasma tilts the plasma mirror. This is done using coils placed around the plasma. These coils are placed so as not to block the microwave signal. A 50 by 60 cm plasma mirror has been generated, for which the measured antenna patterns had sidelobes approximately 20 dB down.<sup>39</sup>

# 95 GHz Reflect-array Using 4" MMIC Wafers

Colin $^{38}$  described a very aggressive effort wherein an MMIC was taken to the point of wafer integration — 4" wafers. Specifically, Thales has built

an experimental missile seeker antenna, which uses two 4" wafers. 38 One wafer has the dipole elements and one bit PIN diode phase shifters printed on it. The second 4" wafer contains the driving circuits that are linked to the first through bumps. The antenna has 3000 elements. The beam width is 2° and can be steered ±45°. They have reported having obtained low sidelobes. 38

# Micro-electro-mechanical System (MEMS) Components

The MEMS integrated circuit mechanical switch holds the promise for a 4-bit X-band phase shifter having low loss (1.5 dB), low power consumption (1 mW) and low cost (\$10 per phase shifter).<sup>70</sup> If such a phase shifter bears fruit, it would be possible to revert back for some applications to the passive phase-phase scanned array architecture having one power amplifier feeding many low cost phase shifters. Instead of a tube, the power amplifier could be a solid-state amplifier. This could reduce the number of T/R modules needed and hence the cost of a phase-phase scanned array by a considerable amount. The MEMS technology is being funded by DARPA.<sup>70</sup> They are looking at using MEMS in their RECAP program to obtain reconfigurable ultra-wideband antennas for multi-user applications as done with the ASAP program described above. 74,75

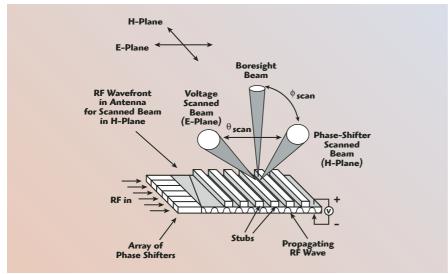


Fig. 12 Low cost 2D electronically scanned antenna approach based on two technologies: CTS antenna architecture and VVD materials.

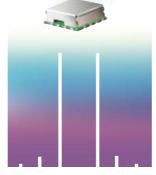
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LAVI-22VH+	425-2200	525-2400	100-700	+21	+31	+20	7.7	50	45	24.95
LAVI-2VH+	2-1100	2-1100	2-1000	+23	+34	+23	7.5	48	47	24.95
LAVI-25VH+	400-2500	650-2800	70-1500	+23	+32	+20	7.5	50	45	24.95

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# Low Cost Phase Array for the Automobile

One tends to think of phased arrays as expensive. A low cost 77 GHz phased array has been developed for automotive intelligent cruise control radar, whose total consumer cost needs to be less than \$300.<sup>72,73</sup> Two antennas, one for transmit and one for receive, and their beamformer networks are photo-etched on a single sheet of copper clad dielectric. The

antennas consist of series fed columns of patch radiators, while the beamformers are Rotman lens, one for each array. The beams are scanned in azimuth by switching between input ports of the Rotman lens.

### CONCLUSION

Based on the above accomplishments, ongoing developments, research and large numbers of programs that are looking to effectively use

phased arrays, it is apparent that the future for phased arrays is very promising and should lead to exciting developments. Phased arrays have come a long way and can be expected to make major strides in the future. For further reading on recent developments in phased arrays around the world, the reader is referred to References 1 to 14, 40, 46, 62, 82 and 83. ■

### **ACKNOWLEDGMENT**

The author would like to thank Doug Venture of the Raytheon Co. for his help.

### **REFERENCES**

Due to space limitations, the large number of references used in this article can be found on the *Microwave Journal* web site at www.mwjournal. com.



Eli Brookner has been at the Raytheon Co. since 1962, where he is a Principal Fellow. There he has worked on the ASDE-X radar, ASTOR Air Surveillance Radar, RADARSAT II, Affordable Ground Based Radar (AGBR), major Space Based

Radar programs, NAVSPASUR S-band upgrade, ČJR, COBRA DANE, PAVE PAWS, MSR, COBRA JUDY, THAAD, Brazilian SIVAM, SPY-3, AEGIS, BMEWS, UEWR and COBRA DANE Upgrade. Prior to Raytheon he worked on radar at the Columbia University Electronics Research Lab [now RRI], Nicolet and the Rome AF Lab. He was awarded the IEEE 2003 Warren White Award for Excellence in Radar Engineering "For Significant Advances in Development and Education of Phased Array Radars." He is a Fellow of the IEEE, AIAA and MSS. He has published four books, the most recent being Tracking and Kalman Filtering Made Easy, John Wiley & Sons Inc., 1998. His previous three books were Practical Phased Array Antenna Systems (1991), Aspects of Modern Radar (1988) and Radar Technology (1977), all published by Artech House Inc. He gives courses on radar, phased arrays and tracking around the world. He was banquet speaker and keynote speaker six times. He has over 110 papers, talks and correspondences to his credit. In addition, he has over 80 invited talks and papers. For one paper he has received the Journal of the Franklin Institute Premium Award. For another he (along with his coauthors) received the Wheeler Prize for Best Applications Paper for 1998. He received his BEE degree from The City College of the City of New York in 1953, and his MEE and DrSc degrees from Columbia University in 1955 and 1962, respectively.

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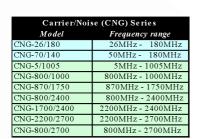
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### **ELECTRICAL SPECIFICATIONS**

PARAMETER	Min	TYP	Max	Unit	Notes
Frequency	430		470	MHz	50% in band
Small Signal Gain	75		80	dB	
VSWR In/Out			1:2:1		
P1 dB Comp.	63.5	64.0		dBm	
Harmonics Out II, III	60	65		dBc	
Gain Tracking		±0.2	±0.3	dB	Unit-to-unit
Phase Tracking		±2.0	±3.0	degree	Unit-to-unit
VSWR Withstand Under Full	Power		∞:1		All phases
Efficiency	52	57		%	
Duty Cycle			15	%	



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FACT #2: TRIQUINT MOVES WITH ITS MARKET, TIMING NEW GSM / EDGE AND WCDMA RELEASES TO THE NEEDS OF MAJOR HANDSET MANUFACTURERS ACROSS THE GLOBE.

Long prized for their strength and dependability, horses are also renowned for their loyalty and sure footedness. Foals can stand right after birth, and working horses have been a friend to mankind since pre-history.

TriQuint's strength is our heritage in high-reliability GaAs and SAW products with expertise that embraces the entire RF front-end of handset engineering. Loyal to our customers, TriQuint ships products with unswerving attention to their high volume production needs.

Like the resourceful horse, TriQuint leads the field with new designs for GSM handsets, and the successor 2.5G and 3G standards. This new year is no exception, and TriQuint will reveal advancements at upcoming industry events, including the GSM World Congress in Barcelona – a field broad enough to help our customers beat competitors to the finish line.

New Designs for New Generations: In 2005, TriQuint extended the success of our TQM6M4001 transmit module family

to include solutions optimized for an even wider range of transceivers. These remain the most highly integrated, smallest products of their kind on the market.

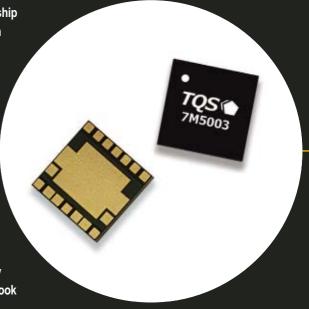
A breed apart from the rest. We're now perfecting new designs for EDGE based on those

innovations, building in the know-how that allows us to design industry-leading PA modules for both polar and linear architectures. Look for exciting announcements designed to satisfy the rigorous demands of next-generation designs and new modules tailored to fit the shrinking PCB real estate afforded to the RF front-end.

Integration That Leads the Field: TriQuint is building on its leadership in SAW and GaAs RF front-end products and an appreciation for the size and space rigors of next-generation EDGE and WCDMA designs. Look for highly integrated products including new PA duplexer modules and designs that incorporate the latest in pHEMT switches, filtering and power amplifiers that could offer customers extended talk time for their mobile devices.

Leadership for the New Year: TriQuint's new designs for GSM, EDGE and WCDMA are all built around an understanding of how far and how fast the world is moving toward new mobile devices that incorporate greater functionality into ever-shrinking form factors. As you look for a partner with greater market awareness, plus products with better battery conservation and higher level integration, look to a winner.... Look to TriQuint Semiconductor.

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**Degrees of Control Range** 

- Temperature Compensation
- Space Qualification and Screening to MIL-PRF-38534/MIL-STD-883



		LUW	NOISE OCTA	VE DAIND AIMPLII	TIEKS	
Model No.	Frequency	Gain	Noise Figure	Output Power (dBm)	3rd Order ICP	VSWR
	ĠHz	dB MIN	dB	MIN @ P1 dB Comp PT	dBm TYP	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-E	BROAD	BAND & MU	LTI-OCTAVE BAN	ND AMPLIFIE	ERS
Model No.	Frequency	Gain	Noise Figure	Output Power (dBm)	3rd Order ICP	VSWR
	ĠHz	dB MIN	dB	MIN @ P1 dB Comp PT	dBm TYP	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 BA	ND 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:	OHE	05 1 111 1	<b>3</b> 5	Till C T T GD Comp T T	QDIII I I I	1000
CA01-2110 CA01-2112 CA12-3116 CA23-3110 CA23-3110 CA34-2110 CA56-3110 CA78-4110 CA910-3110 CA1819-4110 MEDIUM POV	0.4 - 0.5 0.8 - 1.0 1.2 - 1.6 2.2 - 2.4 2.7 - 2.9 3.7 - 4.2 5.4 - 5.9 7.25 - 7.75 9.0 - 10.6 13.75 - 15.4 17.7 - 18.3	28 28 25 30 29 28 40 32 25 25 20	0.75 MAX, 0.45 TYP 0.75 MAX, 0.45 TYP 0.75 MAX, 0.5 TYP 0.75 MAX, 0.5 TYP 0.7 MAX, 0.5 TYP 1.0 MAX, 0.5 TYP 1.0 MAX, 0.5 TYP 1.2 MAX, 1.0 TYP 1.4 MAX, 1.2 TYP 1.6 MAX, 1.5 TYP 2.0 MAX, 1.8 TYP	+10 +10 +10 +10 +10 +10 +10 +10 +10 +10	+20 +20 +20 +20 +20 +20 +20 +20 +20 +20	2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1
CA12-3114 CA23-4110 CA34-6116 CA56-5114 CA812-6116 CA1213-7110 CA1218-5116 CA1415-7110 CA1722-4110 CA1718-4110	1.35 - 1.85 2.7 - 2.9 3.1 - 3.5 5.9 - 6.4 8.0 - 12.0 12.2 - 13.25 12.0 - 18.0 14.0 - 15.0 17.0 - 22.0 17.7 - 18.1	30 32 40 30 30 28 35 30 25 25	4.0 MAX, 3.0 TYP 4.0 MAX, 3.0 TYP 4.5 MAX, 3.5 TYP 5.0 MAX, 4.0 TYP 6.0 MAX, 5.5 TYP 6.0 MAX, 5.5 TYP 5.0 MAX, 4.0 TYP 3.5 MAX, 2.8 TYP 5.0 MAX, 4.5 TYP	+33 +35 +35 +30 +33 +33 +30 +30 +21 +27	+41 +43 +40 +41 +42 +40 +40 +31 +37	2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1
		C	OMPETITIVE P	RICING OFFERE	D	

				I MICHAG OTTEMED	
Model No.	Frequency GHz	Gain dB MIN	Noise Figure dB	Output Power (dBm)	Unit Price
	UHZ	OR MILIA	αB	MIN @ P1 dB Comp PT	Qty 1-9 \$US
CA12-A02	1.0-2.0	26	1.6	+10	Qty 1-9 \$US \$ <b>395</b>
CA24-A02	2.0-4.0	26	1.8	+10	\$ <b>395</b>
CA48-A02	4.0-8.0	24	2.0	+10	\$ <b>395</b>
CA812-A02	8.0-12.0	22	2.5	+10	\$ <b>395</b>
CA1218-A02	12.0-18.0	16	3.5	+10	\$ <b>395</b>

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\$1.3 B Contract

Modification
for JLENS

Development

Raytheon Co. received a \$1.3 B contract modification from the US Army for system development and demonstration of the Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS). Raytheon's Integrated Defense System (IDS) JLENS provides a

long-duration, wide-area cruise missile defense capability, while also providing elevated communications capabilities and supporting situational awareness for the battlefield commanders. The system provides over the horizon detection and tracking of incoming cruise missiles with sufficient warning to enable air defense systems to engage and defeat the threat. Each JLENS consists of a long-range surveillance radar and a high performance fire control radar, each integrated in a large aerostat connected via tether to a ground-based processing station. System testing is scheduled to begin in 2009, with program completion in 2011. "The JLENS program provides unprecedented capability to our warfighters through the combination of long-range surveillance with precise tracking to support engagement of a variety of targets over extremely large geographic areas," said Tim Carey, vice president of IDS Integrated Air Defense. "The program is an important piece of the Army's strategy to provide a reliable and robust cruise missile defense by using a network of sensors to support a wide variety of weapons within the Army system of systems command and control paradigm." Work on the program will be performed at Raytheon sites located in Massachusetts, California, Texas and Maryland. Raytheon's Integrated Defense Systems will develop the fire control radar and processing station. TCOM, LP, based in Maryland, will develop the aerostat and associated ground equipment. Based in Tewksbury, MA, Integrated Defense Systems is Raytheon's leader in joint battlefield integration. With a strong international and domestic customer base, including the US Missile Defense Agency, the US Armed Forces, Integrated Defense Systems provides a wide spectrum of integrated air and missile defense and naval and maritime warfighting solutions.

Northrop Grumman
Awarded Contract
to Produce RQ-4B
Global Hawks

The US Air Force has awarded Northrop Grumman Corp. a contract to begin production of the next five RQ-4B Global Hawk aerial reconnaissance systems. The new \$60 M contract will allow the company to start purchasing long-lead parts for the unmanned air vehicle,

the enhanced integrated sensor suites for four of the air vehicles, one mission-control element and one launch-

and-recovery element. Production of the hardware for these five new RQ-4B air vehicles is expected to begin late this year, with assembly starting next year. "This contract demonstrates the commitment and continued confidence that the Air Force has in Global Hawk's capabilities and operational performance, and the need for this unique intelligence, surveillance and reconnaissance system," said George Guerra, Northrop Grumman's Air Force Global Hawk program manager. "These vehicles will be the first operational Global Hawks with full multiintelligence capabilities, including signals intelligence." Northrop Grumman is currently producing five RQ-4B Global Hawks at its manufacturing facility in Palmdale, CA, as part of several previous limited-production contracts. The new RQ-4B Global Hawk is designed to carry 3000 pounds of payload, 50 percent more than the original RQ-4A configuration. This increased capability will allow the Air Force to install additional sensors on the air vehicle, increasing the amount and types of information available to warfighters. Global Hawk flies autonomously at an altitude of more than 60,000 feet, above inclement weather and prevailing winds, for more than 35 hours at a time. During a single mission, it can provide detailed intelligence, surveillance and reconnaissance information in near-real time over 40,000 square miles — approximately the size of Illinois.

Boeing Awards
Harris Corp. \$2.8 M
Development
Contract for
NOAA's GOES-R

arris Corp. announced that it has been awarded a six-month, \$2.8 M program definition and risk reduction (PDRR) contract by the Boeing Co. for the ground processing segment of the National Oceanic and Atmospheric Administration (NOAA) geostationary operational

environmental satellite – series R (GOES-R) program. When ready to launch in 2012, GOES-R will feature highly advanced sensor technology and will provide much higher resolution and data frequency than the current GOES spacecraft family. Value of the GOES-R PDRR work for Harris could reach \$8 M by 2007 if NOAA exercises all its options for this phase of the contract. Under the GOES-R contract with Boeing, Harris is responsible for the design and development of the GOES-R ground segment. This includes developing a data processing and command-and-control ground prototype for the overall satellite system architecture. The PDRR phase will end with a "fly-off" competition in 2007, with NOAA selecting a single team for development and production of the end-to-end system. "We are extremely pleased to have this opportunity to work with Boeing to develop a processing system that will support the next generation of geostationary weather satellites for NOAA," said Al Dukes, president of the Civil Programs business unit of Harris Corp.'s Government Communications Systems Division (GCSD). "GOES-R rep-





resents a quantum leap in the quantity, timeliness and accuracy of remotely sensed meteorological data. We look forward to fielding a winning prototype solution for the Boeing team." GOES-R will carry several operational instruments, including the 16-channel Advanced Baseline Imager, which will provide visual and infrared imagery of the Western Hemisphere every five minutes; a Hyper-spectral Environmental Suite, which will provide full disk atmospheric soundings to assist in severe weather forecasting; an extended Solar X-Ray Imager; and a Space Environment Monitoring Suite, which will monitor the effects of solar activity on the Earth's atmosphere. This suite of instruments will produce over 100 times the information provided by the current system and will offer a wide variety of unique observations of the environment, with particular emphasis on severe weather and hurricane activity in the Western Hemisphere. Harris ground data processing systems consist of complex suites of hardware and software that receive sensor data from satellites and process it into useable environmental parameters under stringent timelines, turning the data into useable information. The company's command and control systems feature commercial-offthe-shelf (COTS) design and high levels of flexibility. Designed for government and commercial applications, they support single-satellite missions as well as the largest and most complex satellite fleets deployed today.

# L-3 Communications Awarded \$11 M Contract to Provide Cryptographic Unit

L-3 Communications announced that its Communication Systems-East (L-3 CS-East) division has been awarded a contract by Lockheed Martin to design and develop the TRANSEC COMSEC Unit (TCU) for the Mobile User Objective System (MUOS), a next-generation narrowband tac-

tical satellite communication system that will provide significantly improved and assured voice and data communications for the mobile warfighter. Lockheed Martin Space Systems, Sunnyvale, CA, is the prime contractor and system integrator for MUOS, which will replace the current narrowband tactical satellite communications system known as the Ultra High Frequency Follow-On (UFO) system. The US Navy's Communications Satellite Program Office, based in San Diego, CA, is the government agency responsible for acquiring MUOS and narrowband satellite communications for the Department of Defense (DoD). The value of the initial contract award to L-3 Communications is approximately \$11 M for delivery of the first two flight units and a spare flight unit in 2007. L-3 CS-East will provide the crypto units to Lockheed Martin facilities in Newton, PA, where MUOS satellites will be developed.





for internal point-to-point interconnections within RF systems. These high-performance coaxial cable assemblies, ideal for complex, congested environments where increased strength, bending, pulling, and limited twisting are required, perform up to 65 GHz without the expense of armor. The minibend® R ruggedization provides built-in protection that renders significant improvements in mechanical performance, such as a 70% increase in cable retention force over the standard minibend®. This ruggedization helps minibend® R cable assemblies withstand torque yet still allows them to "bend to the end" at an affordable price. minibend® R is ideal for complex assembly level handling in congested environments and eliminates the need for costly right angle connectors due to its low profile. minibend® provides exceptional performance with the added benefits of improved operating frequency range, lower attenuation and lower VSWR.

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Model	Freq. Range (MHz)	Small Signal Gain (dB) Typ.	Noise Figure (dB) Typ.	Power Output at 1dB Comp. (dBm) Typ.	Intercept Point 3rd/2nd (dBm) Typ.	Volts Nom.	.C. mA Typ.
AS2092	30-2000	18.0	<1.5	21.5	38/50	5	100
AC688	200-600	21.5	8.0	22.0	33/45	5	85
AC1292	30-1400	18.5	<1.3	22.0	36/50	5	100
AS3094	400-3000	14.8	<1.7	23.8	37.5/45	15	108
ARS3087	200-3000	19.0	3.0	24.0	35/51	15	165
AR4029	200-4000	22.0	<2.5	26.0	38/53	15	188
AR1096	600-1000	14.2	2.1	28.0	42/58	15	230
ACP7019	3000-7000	14.0	3.1	27.5	35/55	12	250
AR3098	500-3000	11.5	3.5	29.5	43/57	15	335
A3CP8049	2000-8000	22.5	4.4	30.0	38/55	12	550

Specifications are typical. See individual data sheet for details.



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# International Report

Richard Mumford, European Editor

West African
Regulators Agree to
ICT Regulatory
Framework

In a landmark agreement aimed at creating a harmonized information and communication technology (ICT) market, regulators from 15 West African nations have agreed to a common regulatory framework for their national ICT markets. The agreement marks a significant step forward

for the region, which is seeking to create a single market based on the European Union model.

Regulators hammered out the new framework during a validation workshop when more than 100 participants took part, including representatives from the regulatory authorities of Burkina Faso, Cape Verde, Côte d'Ivoire, Ghana, the Gambia, Guinea, Liberia, Mali, Niger, Nigeria, Senegal and Togo as well as regional organizations including CATIA, the Economic Community of West African States (ECOWAS), the European Commission, the FCC, the West African Monetary Union (UEMOA), USAID and members of the private sector.

By favouring a market-based approach to the provision of ICT services, the new guidelines are designed to spur investment and development in the West African ICT sector. Once widely adopted, it is hoped that they will prove instrumental in helping propel some of the world's poorest nations into the Information Society.

SpaceForScience
Programme Targets
South Eastern
Europe

Alcatel Alenia Space has entered into partnership with the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the European Space Agency (ESA) in the frame of the SpaceForScience programme. This is aimed at providing telecommunications.

tion and multimedia satellite services for education and research institutes in South Eastern Europe.

The programme facilitates the scientific and technical cooperation within various scientific communities in Europe and especially in Southern and Eastern Europe. Using satellite technology, scientific institution members of the programme are able to benefit from new services. The programme provides added value broadband services via a satellite applications platform provided and hosted by Alcatel Alenia Space in Cannes, France. The company is responsible for the deployment of the global network, from the applications platform to the user sites.

The company's president and CEO, Pascale Sourisse, said, "Alcatel Alenia Space was eager to provide broadband satellite connectivity to the scientific community within the UNESCO initiative. This technology enables the provision of broadband access and added value applications to isolated institutions and enhances the cooperation in Europe. In a

second step, this programme can be replicated and enlarged to benefit other countries in the world."

45 nm System
Collaboration
for Toshiba
and NEC

Toshiba Corp. and NEC Electronics Corp. have agreed to collaborate on the development of CMOS logic process technology for the 45 nm generation. As advances in semiconductor process technologies become more complex, time consuming and expensive, the joint development will

allow the companies to share burdens and accelerate development, while raising system LSI performance and quality.

Under the terms of the agreement, engineers from both companies will collaborate at Toshiba's Advanced Microelectronics Centre in Yokohama, Japan, on development of fundamental CMOS process technology, which they will be able to implement at their manufacturing facilities. The companies will also separately discuss how to handle the development of value-added and differentiated process technologies. The companies have also begun to discuss comprehensive collaboration in development, such as design environments and product development, as well as collaboration in manufacturing to achieve more efficient use of capital investment and increase capacity utilization rates.

# Technology Transfer in UK Gets Academic Boost

against the backdrop of the UK government's continued emphasis on using innovation to drive economic growth, QinetiQ announced the creation of the UK's first professorship in technology transfer in the physical sciences. The £1 M professorship, which is jointly funded by QinetiQ and

the Engineering and Physical Sciences Research Council (EPSRC), has been awarded to Imperial College London.

The professor's role will be to lead academic research to establish reliable mechanisms, which develop wealth-creating products and services from physics-based sciences. An appointment will be announced in spring 2006 to commence in September 2006. The professorship is one element of an extensive programme of university collaboration announced by QinetiQ. Building on existing links with universities in the UK and overseas, the defence and security technology company has launched a university partnership programme to provide new market opportunities for university science and technology through joint bidding, joint programmes of work and the sharing of resources.

Professor John O'Reilly, chief executive of EPSRC, added, "The UK produces research of international quality in a range of disciplines, from maths to materials science, and from IT to structural engineering, and there is

# International Report



an increasing need to accelerate the translation of the knowledge generated into innovation. This new professorship will ensure that the UK's ability to transfer research into technological change becomes an even more effective driver of the knowledge economy in the future."

Semiconductor
Industry Reports
on Competitiveness

Following the publication of the first EECA-ESIA European Semiconductor Industry: 2005 Competitiveness Report a high level meeting was held to highlight and discuss its findings. Europe's Enterprise and Industry Commissioner, Günter Verheugen and the European Semiconduc-

tor Industry Association (ESIA) discussed the report and how the semiconductor industry in Europe can maintain and enhance its competitiveness. A delegation of ESIA members from STMicroelectronics, Infineon, Philips, Freescale Semiconductor, Micron and Robert Bosch, focused on key findings and how they link to the Commission's initiatives to boost Europe's competitiveness.

The report portrays a comprehensive picture of a sector, which is able to produce record growth rates, making sub-

stantial contributions to the development of the European economy, and to lead state-of-the-art technology innovation. It has created worldwide leading centres of excellence in various locations across Europe. With up to 20 percent of annual revenues re-invested in R&D, and furthermore up to 25 percent in capital expenditures, semiconductor companies are at the top of Europe's innovation list. Despite a continuous rise of the Asia-Pacific region and declining total shares of other regions, Europe has been able to maintain a relative stable market share of around 20 percent.

ESIA proposes ten concrete measures to boost competitiveness. These include promoting a generalized tax credit system on R&D spending, adopting the Commission's original R&D 7<sup>th</sup> framework proposals, reversing the European brain drain, promoting more and stronger multiple partnerships, establishing a sectoral framework, ensuring consistent and efficient customs operations, and pooling expertise in the EU and national institutions.

Carlo Bozotti, president of ESIA and CEO of ST-Microelectronics, commented, "Semiconductors are the enabling technology for the Information Society, and their contribution to the success of the European economy is essential. The semiconductor industry in Europe has mobilized all its energy to face the challenges highlighted in the report. By communicating its call for action, ESIA hopes that the report will serve as a catalyst for implementing measures that reflect the real needs of our industry."

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- · Integrated antenna/radome systems
- Leading-edge tools for assessing installed performance
- Exceptional reliability



## **Unique Solutions to Complex Problems**

- Slotted waveguide arrays
- EW antennas
- CNI antennas
- Electronically scanned arrays
- Radomes, FSS, and RAM/RAS

### **Advanced Manufacturing**

- Integrated electrical, mechanical, and M&P engineering design team
- Extensive manufacturing facilities and resources
- · Automated RCS, nearfield, and farfield test
- CMM, Laser Radar, and Digital X-ray inspection





# Coaxial

50 to 2650MHz from \$37.95 (eq. (Qty. 1-9)

Mini-Circuits family of ZX95 voltage controlled oscillators offers a generous variety of high performance solutions for your instrumentation, test, R&D, system, lab, and production needs! The series features linear tuning across each band and exceptionally low noise. Choose from models with octave or near octave-band tuning, excellent harmonic suppression, low pushing & pulling, and a wide range of tuning voltages and output powers to suit your particular application. ZX95 VCOs also employ our patented Unibody construction, which substantially reduces size and cost while enhancing repeatability.

All models are IN STOCK for "no wait" shipments, and custom needs will be met with our fast follow-up!

Mini-Circuits...we're redefining what VALUE is all about!

(L) 1.20"x(W) 1.18"x(H) 0.46"

J		*						
	SERIES Model No.	Freq. (MHz) Min. Max.	Pout (dBm) Typ.	Phase Noise* Typ.	V <sub>TUNE</sub> (V) Max.	Harmonics (dB) Typ.	Current (mA) Max.	Price \$ea. (1-9)
	Model No.	IVIIII. IVIAA.	ıyρ.	ıγp.	iviax.	īyρ.	iviax.	(1-9)
	ZX95-100	50-100	10.0	-110	17	-33	20	37.95
	ZX95-200	100-200	10.0	-106	17	-30	20	37.95
	ZX95-400	200-380	10.0	-104	17	-25	21	39.95
	ZX95-535	300-520	6.0	-101	17	-25	21	39.95
	ZX95-765	485-765	8.0	-98	16	-35	22	40.95
	ZX95-1200W	612-1200	10.0	-96	18	-16	30	49.95
	ZX95-1410	850-1410	8.0	-101	11	-17	30	44.95
	ZX95-1600W	800-1600	9.0	-99	24	-22	35	44.95
	ZX95-1700W	770-1700	9.0	-100	24	-25	35	49.95
	ZX95-1900V	1450-1900	8.0	-104	20	-20	25	42.95
	ZX95-2150VW	970-2150	4.0	-99	25	-22	26	54.95
	ZX95-2500	1600-2500	7.5	-91	14	-17	28	46.95
	ZX95-2650	2165-2650	5.0	-101	19	-12	25	43.95
	*Phasa Maisa: S	SR at 10kHz	offeat o	Bc/Hz				

U.S. Patent Number 6,790,049

Detailed Performance Specs and Shopping Online at: www.minicircuits.com/vco.shtml





CIRCLE READER SERVICE CARD

# DIGITAL ATTENUATORS

0.5 to 31.5dB in 0.5 and 1dB Steps



24 Models To Choose From

• Choose single +3V or dual +3V, -3V supply voltage @ 100μA

- · Select 5 or 6 Bit, serial or parallel interface
- Up to 31.5dB, either 0.5 or 1dB steps
- High attenuation accuracy, 50 or 75 ohm
- Very high IP3 +52 dBm, 0.2 dB compression @ +24 dBm above 1 MHz
- CMOS programmable start-up and always immune to latch-up

From world-class performance to very competitive prices, count on Mini-Circuits DAT digital attenuators for the solutions to fit your needs!

Exposed Metal Bottom Top View Me Small 4x4mm Package.

DAT SELECTION GUIDE

Specifications Typical at: T<sub>AMB</sub> = 25°C Steps Bits Price \$ea. dB (Qty.10) **Model Series** Interface Z (Ω) Freq. MHz dB DAT-15R5-P ▲ DC-4000 15.5 0.5 DAT-15R5-S ▲ DC-4000 0.5 3.55 DAT-15575-P ▲ Parallel DC-2000 15.5 0.5 3.55 DAT-15575-S ▲ Serial DC-2000 15.5 0.5 3.55 DAT-31-P ▲ Parallel DC-2400 31.0 1.0 3.55 3.55 DAT-31-S ▲ Serial 50 DC-2400 31.0 1.0 DAT-3175-P ▲ Parallel DC-2000 1.0 3 55 3.55 DAT-3175-S A Serial DC-2000 31.0 1.0 DAT-31R5-P ▲ Parallel DC-2400 0.5 3.80 DAT-31R5-S ▲ Serial DC-2400 31.5 0.5 3.80 DAT-31575-P ▲ Parallel 75 DC-2000 31.5 3.80 DAT-31575-S ▲ Serial DC-2000

▲To specify Supply Voltage: Add the letter (P) to model number for positive +3 volts

Add the letter (N) to model number for Dual  $\pm 3$  volts.

Example: DAT-15R5-PP or DAT-15R5-PN Patent Pendina



Detailed Performance Specs and Shopping Online for our surface mount and coaxial models at: www.minicircuits.com/dsa.shtml





CIRCLE READER SERVICE CARD

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: www.minicircuits.com

# Commercial Market



# Breaking Stalemates: What Does the EWC Announcement Mean for 802.11n?

ne of the Wi-Fi industry's most closely watched stalemates received a new twist. Faced with a deadlock between two competing groups and proposals for the shape of an 802.11n protocol standard, TGn Sync and WWiSE agreed to build a combined proposal that

would forge a compromise between the two industry associations. However, the working group had not yet devised a specification for the combined proposal, when news reached the market that four major companies — Broadcom, Intel, Atheros and Marvell, holding the lion's share of the Wi-Fi market — had formed a third camp with the aim of writing a whole new proposal. It is now known that the breakaway group consists not of four companies, but 27, calling themselves the Enhanced Wireless Consortium (EWC). The EWC has now released its specifications for 802.11n, saying, "by introducing a specification with widespread industry support, the EWC hopes to speed ratification of an 802.11n standard, while enabling an ecosystem of high performance WLAN products built to a common set of guidelines. This widely accepted specification will benefit consumers by, among other things, ensuring the interoperability of next-generation wireless products across a variety of brands and platforms." While appearing to preempt the IEEE working group's efforts, the EWC said that some of its members, many of whom belong to TGn Sync or WWiSE, "will continue to work within the IEEE Task Group 'N' to facilitate a ratified 802.11n standard." What does it mean for the industry and for consumers? ABI Research senior analyst Philip Solis says, "This announcement means that companies can start building EWC-compliant Wi-Fi chipsets and products immediately, with EWC-compliant probably reaching the market by the fourth quarter of 2006. The result will be MIMO Wi-Fi products that are more than just interoperable with existing Wi-Fi products; EWC-compliant products will have the full benefits of increased range and throughput with other EWC-compliant products. Whether or not the EWC specification will form the basis of an eventual IEEE 802.11n protocol remains to be seen, but if so, that would mean availability of 'pre-802.11n' systems sooner than might have been expected."

# Explosive Market Growth for SATCOM Antennas

new 465-page report is now available from Engalco on the subject of "SATCOM Antennas — the Worldwide Industry and Market Opportunities to 2012." This report indicates that the overall global market will grow from \$887 M in 2005 to reach \$6.68 B in 2010, that is an

anticipated eight-fold increase in the next five years. Demand is rapidly being driven upwards on many fronts and this report segments market data as follows (mostly covering both commercial and military): aircraft, ground control hubs, VSAT terminals, land mobile, shipping and spacecraft. All types of SATCOM antenna technologies are considered in this report and the market is segmented into dish-reflector-based and flat-panel-based (including phased arrays). A total of 56 company profiles and detailed financial data on the market are provided (123) charts), together with unit prices and shipments in many cases, all with forecasts to 2012. Strongly increasing requirements for two-way broadband Internet connectivity include: rural area needs, sea-going ships, RVs, trucks and to some extent railways. Up-coming military implementations such as WGF, AEHF, the transformational satellite program in the US and Skynet 5 in the UK are also very important. Another significant driving factor is that recently, the FCC has strongly promoted an increase in the use of SATCOM — driven by experiences with recent hurricane disasters like Katrina and Rita. In terms of investments to meet these increasing demands, some broadband satellite constellations have already been launched into orbit (Thuraya and Wildblue, for example). Further commercial and military launches are planned over the years' ahead and these, plus earlier investments, will provide the systems availability for a strong and rapid growth of airborne and terrestrial hardware and services, including SATCOM antennas. For further information, contact enquiries@engalco-research.com.

# Calling from the Troposphere: The Coming Market for In-flight Wireless

Between January 1 and December 31, 2005, a staggering 1.2 billion passengers will have flown on some 28 million flights worldwide. Historically, passengers have been forbidden to use their mobile communications — cellular phones or Wi-Fi-equipped portable devices — in

flight. But that is starting to change. Wi-Fi has been installed on a number of airlines, including Lufthansa, Singapore Airlines and Austrian Airlines. Öthers intend to follow suit. A whole new market is being created. A new study from ABI Research, "In-flight Mobile and Wi-Fi Services: Market Potential and Challenges," provides a comprehensive review and assessment of this complex but potentially lucrative market. It assesses regulatory bottlenecks and technical solutions, as well as forecasting market growth and capital expenditure. Mobile phones were originally banned in flight because they log on to terrestrial networks and cause network management chaos; but they also radiate at their maximum power, and there was concern about possible interference with the aircraft's avionics. Now, companies such as Qualcomm, Siemens and Ericsson have developed pico-cell technologies that will allow the use of both GSM and CDMA mobile

# COMMERCIAL MARKET



phones during flights, without causing any interference. "The in-flight Wi-Fi and mobile communications market holds considerable promise," says ABI Research's director of research for Europe, Jake Saunders, "but regulatory hurdles, satellite communication bandwidth and pricing will constrain the market potential in the short to medium term." ABI Research believes that the market will develop once the regulatory barriers have been removed. For the next five years, much of the activity will be Wi-Fi related, but as regulatory obstacles to mobile communications are removed, their usage on aircraft will build. "We expect that in-flight mobile communications services will start in Europe in 2007," adds Saunders. "Asia will follow, then North America."

# Shipments More Than Double Again

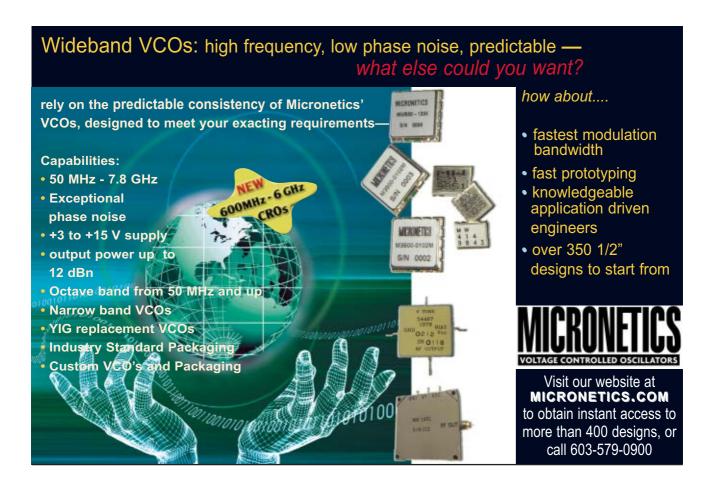
Bluetooth is firmly established as a short-range wireless solution for voice and data transmission, as 2005 will be the fourth consecutive year in which Bluetooth-enabled product shipments more than double, reports In-Stat. This year's shipments are forecast to be 316 mil-

lion units, a total that will rise to 866 million in 2009, the high tech market research firm says. "Mobile phones are at the core of Bluetooth's popularity," says Brian O'Rourke, In-Stat analyst. "They are in turn helping Bluetooth penetrate into other products, including notebook PCs, mono and stereo headsets, automobiles and portable digital music players."

A recent report by In-Stat found the following:

- Bluetooth will need to constantly adapt in the face of competition that includes wireless USB, Wireless 1394 and Wi-Fi.
- Results from In-Stat's Residential Technology Survey (RTS) of typical US consumers indicate increasing recognition of Bluetooth and significant interest in cordless stereo headsets.
- Chips complying with Bluetooth 2.0 + Enhanced data Rate (EDR) are beginning to hit the market in 2005, providing both greater bandwidth and lower power consumption.

The report, "Bluetooth 2005: The Future is Here," provides analysis and five-year unit shipment and revenue forecasts for all Bluetooth-enabled products, including those in the PC, communications and consumer electronics segments. The report also contains responses on Bluetooth and wireless headsets from In-Stat's annual RTS. Brief profiles of major Bluetooth silicon suppliers are also provided.





# **Analog Innovation**



Skyworks offers a portfolio of highly innovative linear products to support a diverse set of markets. Beyond **mobile**. From **automotive** to **broadband**, **industrial** to **medical**, Skyworks will work closely with your team to find the ideal precision analog solution for any design challenge.

Amplifiers • Attenuators • Diodes • General Purpose Amplifiers • Infrastructure RF Subsystems

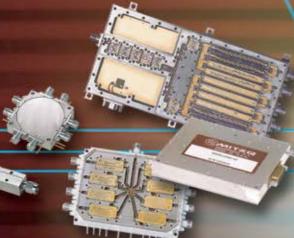
Power Dividers/Combiners • Receivers • Switches • Synthesizers/PLLs • Technical Ceramics • Transmitters

# microwave Components

# **MIXERS TO 60 GHz**

- · Single-, double-, and triple-balanced
- Image rejection and I/Q
- Single-sideband, BPSK and QPSK modulators
- High dynamic range
- Active and passive frequency multipliers





# CONTROL PRODUCTS

- PIN diode switches
- Switch matrices
- PIN attenuators
- Limiters

# INTEGRATED SUBASSEMBLIES TO 60 GHz

- Integrated up/downconverters
- Monopulse receiver front ends
- · Missile receiver front ends
- Switched amplifier/filter assemblies





# IF AND VIDEO SIGNAL PROCESSING

- Logarithmic amplifiers
- Constant phase-limiting amplifiers
- Frequency discriminators
- AGC/VGC amplifiers
- I/Q processors
- · Digital DLVAs



# FREQUENCY SOURCES TO 40 GHz

- Free-running VCOs/DROs
- Phase-locked coaxial resonators
- Synthesizers for SATCOM
- Fast-tuning communication synthesizers

# **AMPLIFIERS TO 60 GHz**

- · Octave to ultra-broadband
- · Noise figures from 0.35 dB
- Power to 10 watts
- Temperature compensated
- Cryogenic
- Space qualified





# PASSIVE POWER COMPONENTS

- Power resistors and terminations
- Power dividers
- Attenuators
- Directional couplers
- 90 degree hybrids

# FIBER OPTIC SYSTEM COMPONENTS

- · Wideband fiber optic links
- Fiber optic transmitters
- Fiber optic receivers
- RZ and NRZ drivers, low noise and limiting amplifiers
- 10 & 12.5 Gb/s modulator drivers
- 40 Gb/s drivers and linear amplifiers





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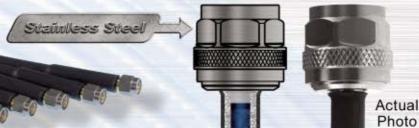
# M

# AROUND THE CIRCUIT

# **INDUSTRY NEWS**

- Microsemi Corp. and Advanced Power Technology Inc. (APT) announced the signing of a definitive agreement for Microsemi to acquire APT. With this acquisition, Microsemi, a designer and manufacturer of high performance analog solutions and high reliability semiconductor solutions, expands its portfolio of analog mixed signal offering in the RF marketplace and also its high reliability offering in the defense/aerospace and medical marketplace. Under the terms of the agreement, each APT shareholder will receive \$2.00 per share in cash and 0.435 shares of Microsemi common stock for each share of APT common stock.
- EMS Technologies Inc. announced the closing of the sale of its Space & Technology/Montreal division to Mac-Donald, Dettwiler and Associates Ltd., Vancouver, BC, Canada. EMS originally announced the signing of a definitive agreement for the sale on October 31st. The two companies have worked to obtain the necessary approvals from the Competition Bureau, Industry Canada pursuant to the Competition Act, customers and other third parties. Final terms of the sale were not disclosed.
- Agilent Technologies Inc. announced an agreement with Auriga Measurement Systems to jointly develop and market integrated device-modeling systems for the semiconductor industry. The companies plan to pair Agilent's IC-CAP parameter extraction and device modeling software and instrumentation with Auriga's test instrumentation. The first system planned is a pulsed-bias/pulsed-RF solution for isothermal characterization and modeling. As part of this agreement, Auriga plans to develop software modules for Agilent's IC-CAP software, providing measurement and hardware drivers to allow data acquisition, and new device model extraction routines for Auriga device models.
- Cascade Microtech is expanding its capabilities in the semiconductor failure analysis market. In August 2005, the company introduced eVue digital imaging system, a new tool for sub-micron probing to ease the problems of failure analysis on rapidly shrinking geometries. Cascade Microtech announced it has entered into a business and technology partnership with Credence Systems Corp. to further expand its failure analysis market penetration. The terms of the relationship were not disclosed.
- Taconic and Modelithics<sup>TM</sup> announced that they have begun a collaboration whereby Modelithics will significantly increase its use of Taconic's high performance printed circuit board substrate materials in developing its substrate-scalable discrete and surface-mount component models for active and passive components.
- TestMart announced an agreement with Ophir RF, a designer and manufacturer of high power, solid-state, broadband and band-specific amplifiers. The deal provides the US government and federal contractor market-place with special pricing on a select catalog of RF power amplifiers. In related news, Summitek Instruments, a

- manufacturer of software products designed to automate spectrum management as well as S-parameter measurements, announced a new partnership agreement with TestMart Inc. TestMart will provide government market-place services to better serve Summitek's diverse United States federal and defense-related customers. The agreement authorizes TestMart to present a special catalog of Summitek products to be made available specifically to the government and military markets.
- Xpedion Design Systems Inc., a provider of next generation RFIC simulation, and Jazz Semiconductor, an independent wafer foundry focused primarily on specialty CMOS process technologies, announced a partnership to deliver a qualified model and simulation environment for next generation RFIC design.
- Andrew Corp. has signed a WCDMA infrastructure patent license agreement with QUALCOMM Inc. Under the terms of the worldwide royalty-bearing agreement, QUALCOMM has granted Andrew a license to develop, manufacture and sell WCDMA picocell and microcell base station systems.
- WiQuest Communications Inc., a fabless semiconductor company focused on the design and production of complete high performance, ultrawideband (UWB) wireless solutions, announced the opening of its first international customer development and sales support center. The new WiQuest office is located at 23F, No. 105, Sec. 2, Tun Hua South Road, Da An District, Taipei City, Taiwan, ROC. The phone number is +886-2-2709-7816 and e-mail is info@wiquest.com.
- Shimadzu Scientific Instruments Inc., a developer of analytical instrumentation, announced the availability of a complete range of analytical instruments to assist manufacturers in attaining Restriction of Hazardous Substances (RoHS) directive and Waste Electrical and Electronic Equipment (WEEE) directive regulatory compliance. In addition, Shimadzu provides all the equipment that companies need to assess ongoing compliance with established end-of-life vehicle regulations.
- Centro de Tecnología de las Comunicaciones S.A. (CETECOM), in Spain, has enhanced its accredited testing service range for the mobile communications industry. CETECOM Spain has been granted ISO 17025 accreditation for testing of 3G technologies, enabling it to offer conformance testing services for 2G/2.5G and 3G technologies, covering RF, protocol, SIM/USIM and audio capabilities.
- The Swiss **HUBER+SUHNER** Group, a global supplier of components and systems for electrical and optical connectivity, has been producing radio frequency products at its subsidiary company in Tzcew/Gdansk, Poland, since 2003. In November 2005, this plant received the ISO/TS 16949 certificate and now represents the company's third site to be awarded a certificate for this exacting automotive standard.



Extended Over Molding

**Heat Shrink Tube** with Adhesive

# Photo

Cable	Construction
Canie	Construction

Туре	Frequency (GHz)	Inner Conductor	Dielectric	Jacket
SF Series	DC-18	Solid Silver-Plated Copper Clad Steel	Solid PTFE	Blue FEP
SFR Series	DC-8	Solid Silver-Plated	PTFE	Gray PVC

### Connectors

Gold Plated Brass Center Contact Passivated Stainless Steel Coupling Nut Captive Contacts PTFE Dielectric



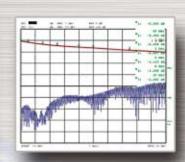




# Features:

- 1. Unique Extended Over Molding for maximum strain relief.
- 2. Heat Shrink Tube With Built-In Adhesive for added durability.
- 3. Rugged Solder-Clamp Construction.
- 4. Excellent Shielding Effectiveness.
- 5. Wide Frequency Range.
- 6. RoHS Compliant.
- 7. -55°C to +105° Storage & Operating Temperature.

Model #	Frequency (GHz)	Length** (ft.)	Connector (Male)	Price * Qty. 1-9
SF2-SMSM	DC-18	2	SMA - SMA	\$44.95
SF3-SMSM	DC-18	3	SMA - SMA	\$52.95
SF2-SMNM	DC-18	2	SMA - Type N	\$72.95
SF3-SMNM	DC-18	3	SMA - Type N	\$77.95
SFR2-SMSM	DC-8	2	SMA - SMA	\$26.95
SFR3-SMSM	DC-8	3	SMA - SMA	\$29.95
* U.S.A. Pricing	Only. ** Other s	sizes are avail	able. Please call.	



For additional information,

contact Synergy's sales and application team. 201 McLean Boulevard, Paterson, NJ 07504 Phone: (973) 881-8800 Fax: (973) 881-8361

E-mail: sales@synergymwave.com Web Site: http://www.synergymwave.com

# Replacement Guarantee\*

Cable will be replaced within 9 months of shipment if the connector failure is not due to misuse or abuse.



Visit http://mwj.ims.ca/5548-135 or use RS# 135 at www.mwjournal.com/info

# AROUND THE CIRCUIT

- Jacket Micro Devices Inc., an integrator of RF components used in wireless communication products, announced that it has joined the WiMAX Forum, an industry consortia dedicated to promoting and certifying compatibility and interoperability of broadband wireless products.
- RF Micro Devices Inc. (RFMD) announced it has commenced shipments of highly integrated transmit modules to multiple handset manufacturers. Transmit modules are comprised of RFMD's power amplifiers with integrated PHEMT switch technology.
- **ANADIGICS Inc.** announced that the company is shipping production volumes of InGaP HBT power amplifiers to **LG Electronics** for the VX9800 CDMA phone.

# **CONTRACTS**

- Sensors Unlimited Inc. announced it has been awarded a contract by the Defense Advanced Research Projects Agency (DARPA) Microsystems Technology Office to develop a 1280 × 1024 pixel, dual-wavelength, visible and shortwave infrared focal plane array. The contract will be awarded in three, 12-month phases and if fully executed, will total \$4,576,176.
- AR Worldwide Modular RF announced that it has received an order from Amron International for 71 tactical communications amplifiers. The order, for model KMW1030 (20 W, CW 30 to 512 MHz), is the latest in a series of orders from Amron, and is unique in that the amplifiers ordered are specifically for use in "HumVee" fighting vehicles rather than as Man-Pack units. AR Worldwide was awarded the order mainly because of its ability to customize the units and deliver them in a short time period.
- Boeing Co., Kent, WA, has placed a follow-on order for a space qualified hermetically sealed multi-throw switch in support of its Sea Launch Program. Renaissance Electronics has developed mechanical processes to achieve the severe requirements for space flight applications. Renaissance participation in this space flight program further expands the company's ability to support high level defense and space programs.
- RF Industries' RF Neulink Telemetry Division announced it has been awarded an initial contract, valued at approximately \$300,000, for its flagship NL6000 wireless modem for the program manager for training systems, training products and services provider to the US Marine Corps. (USMC). The contract includes \$71,000 of non-recurring engineering expenses procured by SRI International, the USMC's lead systems integrator for range modernization and transformation.

# FINANCIAL NEWS

■ **Ansoft Corp.** reports sales of \$18 M for the second quarter of fiscal 2006 ended October 31, 2005, compared to \$15.9 M for the same period in fiscal 2005. Net income

for the quarter was \$4.1 M (\$0.32/per diluted share), compared to a net income of \$1.9 M (\$0.14/per diluted share) for the second quarter of last year.

# **NEW MARKET ENTRY**

■ Silicon Laboratories Inc., a designer of high performance, analog-intensive, mixed-signal ICs, announced its entry into the frequency control market with the Si530 and Si550 families of oscillators (XO) and voltage-controlled oscillators (VCXO) for applications up to 1.4 GHz. These product families include the quad frequency XO and VCXO devices. Leveraging the company's DSPLL® technology, both the Si530 and Si550 families provide short lead times, high reliability and good performance that make them ideal for applications such as networking equipment, base stations, test and measurement equipment, and storage area networks.

# PERSONNEL

■ Peter W. Staecker has been elected to serve as vice president-elect of IEEE Technical Activities. He will assume the office as vice president on January 1, 2007.



■ Erik Tobiason has accepted the position of president of Vitronics Soltec. Tobiason takes the helm of Vitronics Soltec after five years of serving as president of Graphics Microsystems Inc. (GMI), a Dover Diversified company. Tobiason began his career with Dover as vice president engineering and R&D of GMI.

▲ Erik Tobiason

that it has appointed **Haresh P. Patel** as senior vice president, sales and marketing. Patel brings over 22 years of semiconductor industry experience managing sales, marketing and divisional P&L organizations. Patel replaces Javed S. Patel, who has resigned from his position at the company. Most recently, Patel was vice president, worldwide sales and marketing at Agilent Technologies, where he managed a 350 person sales and marketing organization.



■ Jerry Brown has been named vice president of sales for LBA Technology Inc. Brown will manage sales and distribution of LBA antenna system and related radio frequency products.

picoChip announced it has appointed **Steve Lu** to be the company's vice president sales

Asia Pacific. Most recently, Lu was vice president of marketing and strategy for Sipod Communications in Shanghai, China.



▲ Steve Lu

Aperto Networks, a WiMAX systems provider, announced that it has appointed **Glenn Tamaru** as vice president of operations. Tamaru, who has



# One concept, three faces

The new R&S®ZVx family of network analyzers – the modern alternative

State-of-the-art electronics require state-of-the-art test equipment. Plus impressive solutions in all areas — from measurement speed and features to operating convenience. That's why you should take a close look at the new network analyzers from the R&S\*ZVx family. Each of the three series of instruments is designed for a different set of applications, yet they all share the same concept for operation and remote control.

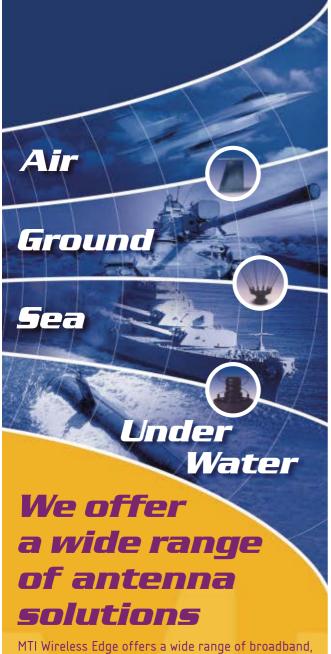
- R&S®ZVA: This high-end analyzer up to 8 GHz or 24 GHz is designed for extremely challenging tasks in the development lab. It sets new standards in numerous areas and is ideal for measurements on active and frequency-converting devices.
- R&S®ZVT8: This is the first and only eight-port analyzer up to 8 GHz on the market. It offers true parallel measurement on all ports and will make your production operations faster than ever hefore
- R&S®ZVB: This all-purpose analyzer is available up to 4 GHz, 8 GHz or 20 GHz. Not only is it flexible in the lab and fast in production, but its innovative and intuitive operating concept will make your job much easier.

With any of the new R&S®ZVx network analyzers, you'll see your circuits through a new set of eyes. Contact your nearest Rohde & Schwarz sales representative for a demonstration now!









MTI Wireless Edge offers a wide range of broadband, tactical and specialized antennas and antenna systems for communications, COMJAM, ESM, ECM, Sigint (Comint and Elint), as well as special UAV applications, spanning the entire frequency range (2MHz-40GHz). MTI's antennas have been installed on various airborne, ground and naval surface and sub surface platforms worldwide. For the commercial market, MTI offers various flat panel antennas for Fixed Wireless and RFID applications.



25 years of operations experience, was most recently vice president of operations at GoDigital Networks in Fremont, CA.



■ IDI/Synergetix announced that **Bruce Valentine** has joined the team by accepting the position of business development manager for connector products in Europe. Valentine will help to guide business growth of the OEM product sales in the European sales region.

▲ Bruce Valentine

■ 4RF Communications has appoint-

ed **Jarlath Lally** to the role of global director of marketing. He will operate from 4RF Europe, based in the UK, where he will be responsible for helping the company to expand its global customer reach, and develop new markets for its wireless networking solutions. Lally has worked for 4RF Communications since January 2005 as a



🔺 Jarlath Lali

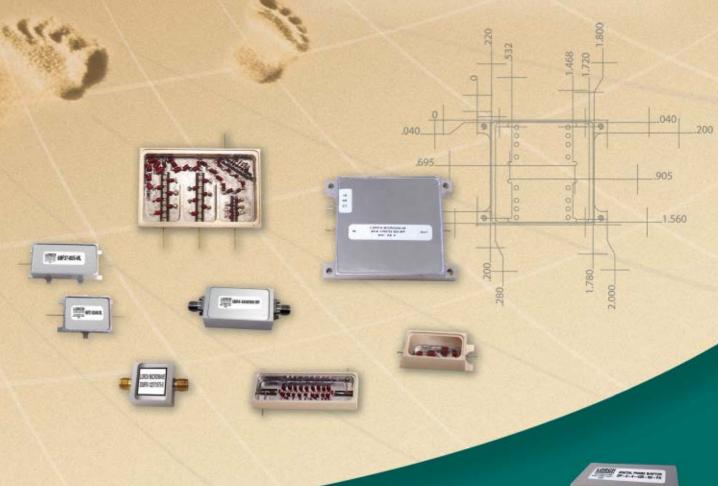
strategic account manager. From 2002 to 2004, he worked as an independent consultant with a client list that included network operators, regulators and ICT equipment vendors. Prior to that he held management roles at Cisco, Stratex Networks and NEC.

■ Comarco Wireless Test Solutions announced that **Carlos Oliu** and **Charles Blount** have joined the company as managers of South American sales and North American sales, respectively. They will also oversee the rapidly expanding distribution networks in their territories. Oliu served as a major accounts executive with Willtech International, marketing wireless testing equipment to carriers. Blount supervised and directed technical sales support and all engineering services sales for wireless test systems at Ericsson.

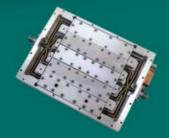
## REP APPOINTMENTS

- Aeroflex has signed a distribution agreement with Maxtronix Inc. to distribute its product portfolio in the Philippines. Under the terms of the agreement, Maxtronix will operate as exclusive distributor for Aeroflex ATE products and services including flying probe test systems, power manufacturing defects analyzers, and in-circuit and combinational testers. The distributor has offices in Paranaque City and Cebu City, dedicated to selling sophisticated equipment for semiconductor, SMT and thru hole assembly technology.
- Nordic Semiconductor and Nu Horizons Asia Ptd. Ltd. announced the signing of a Pan-Asian partnership agreement. This agreement involves the distribution for all of Nordic's products throughout the territories of China, Hong Kong, Taiwan, India, Korea, Malaysia, Singapore, Thailand, Australia and New Zealand.
- MI Technologies announced it has selected Adler Instrumentos S.L., Madrid and Barcelona, to represent the

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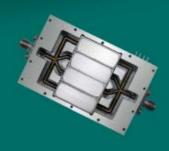
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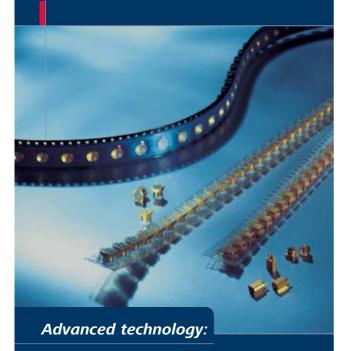
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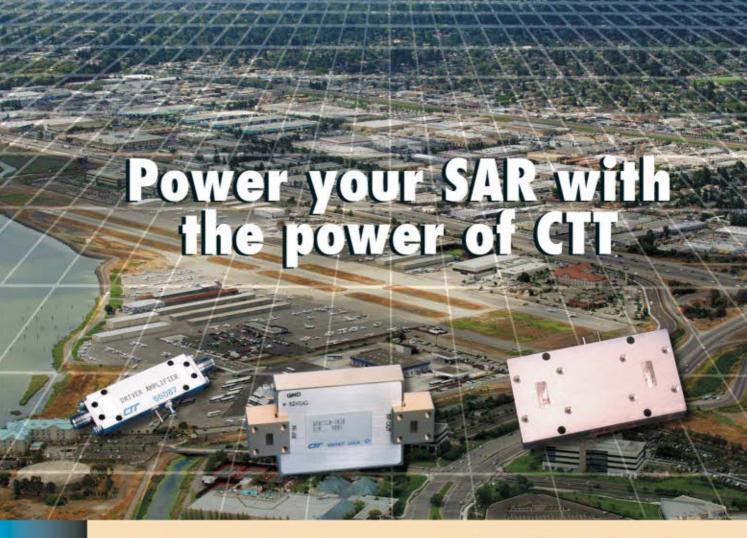
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Phone: +49-86 84-18-0 Fax: +49-86 84-18-499 info@rosenberger.de company's line of RF and microwave test and measurement products to customers in Spain. MI Technologies' automated test and measurement systems are used to evaluate wireless, satellite and telematics antennas, radomes, radar cross section and microwave component characteristics.

- Microtech announced the appointment of Hytech Associates Inc. as its exclusive sales representative for southern California. Hytech can be reached at 717 Lakefield Road, Suite B, Westlake Village, CA 91361 (818) 991-7491, fax: (805) 379-2128 or e-mail: hytech@hyth.com.
- International Manufacturing Services Inc. (IMS), a manufacturer of high quality thick film resistors and substrates to the electronics industry, announced the appointment of **W. Howard Associates Inc.** to represent its products in the states of Colorado, Utah, Montana, Wyoming and Idaho. The company can be contacted at 6770 S. Dawson Circle, Suite 100, Centennial, CO 80112-4224 (303) 766-5755, fax: (303) 766-2488 or e-mail: service@whoward.com. In related news, IMS announced the appointment of **NextWave Technologies** to represent its products in Israel. NextWave can be reached at PO Box 25180, Tel-Aviv 61253 Israel 972-3-9619000, fax: 972-3-9619005 or visit www.nextwave.co.il.
- Wenzel Associates Inc., a manufacturer of precision low noise crystal oscillators and related RF devices, sub-assemblies and synthesizers for the communications, navigation, military and test equipment markets, announced the appointment of **C-Wave Inc.** as the company's representative for southern California. C-Wave can be reached at (310) 937-3521 or visit www.cwaveinc.com.
- RelComm Technologies Inc., a designer and manufacturer of RF coaxial relay products, has appointed **Associate** Technical Sales LLC to represent the company in southern California. For more information, visit www.atslrep.com.
- **Praxsym Inc.** announced the addition of **Winncom Technologies** as a registered distributor for resale of the PM-2458 broadband wireless power meter. Winncom Technologies is a provider of wireless networking solutions, offering a complete selection of unlicensed and licensed wireless data and voice products. For more information on the PM-2458, visit www.vswrmeter.com.

# **WEB SITE**

■ American Technical Ceramics (ATC) introduced expanded product offerings for ATC QUIKBuy<sup>TM</sup>, where customers may place on-line orders for small product quantities. ATC QUIKBuy offers the EIA-size ultra-low ESR capacitors, the 600F (0805) and 600S (0603). ATC has now expanded its on-line product offerings to include the 600L (0402), as well as RF capacitors: the 100A (0505) and 100B (1111). The ATC QUIKBuy Product Selector enables customers to easily select specific capacitance values and case sizes. ATC QUIKBuy also creates an on-line customer profile to expedite repeat orders. Visit www.atceramics.com and select: ATC QUIKBuy.



The confluence of advances in supporting technologies, such as processors and memories — as well as developments in UAVs — coupled with geopolitical demands for increased homeland security and greater intelligence gathering has pushed SAR (synthetic aperture radar) into the ISR (intelligence, surveillance and reconnaissance) spotlight.

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More than twenty years ago CTT, Inc. made a strong commitment to serve the defense electronics market with a simple goal: quality, performance, reliability, service and on-time delivery of our products.

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# CTT Power and Driver Amplifiers for SAR

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Band	Frequency	Up to	Bandwidth
X-Band	7.5 - 10.5 GHz	40 Watts	10%
X-Band	7.5 - 10.5 GHz	80 Watts	500 MHz
Ku-Band	14 - 17 GHz	20 Watts	10%
Ka-Band	32 - 37 GHz	10 Watts	10%

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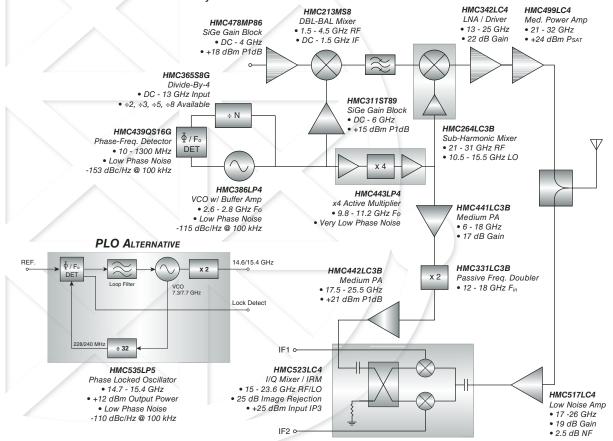


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	HMC441LP3	HMC441LP3	HMC441LC3B	HMC441LC3B	HMC498LC4	HMC498LC4	HMC499LC4	HMC499LC4	HMC300LM1
Driver Amplifier	HMC451LC3	HMC451LC3	HMC451LC3	HMC451LC3	HMC383LC4	HMC383LC4	HMC383LC4	HMC383LC4	HMC383LC4
	HMC516LC5	HMC516LC5	HMC490LP5	HMC490LP5	HMC442LC3B	HMC442LC3B	HMC283LM1	HMC283LM1	HMC283LM1
Power Amplifier	HMC486LP5	HMC487LP5	HMC489LP5	HMC489LP5	HMC498LC4	HMC498LC4	HMC499LC4	HMC499LC4	HMC283LM1
Mixers:	HMC144LC4	HMC144LC4	HMC144LC4	HMC144LC4	HMC144LC4	HMC292LC3B	HMC292LC3B	HMC292LC3B	HMC329LM3
Fundamental	HMC219MS8	HMC412MS8G	HMC412MS8G	HMC260LC3B	HMC260LC3B	HMC260LC3B	HMC329LC3B	HMC329LC3B	HMC294
Mixer: Sub-Harmonic				HMC258LM3	HMC258LM3	HMC264LC3B	HMC264LC3B	HMC265LM3	HMC338 HMC339
Mixer: I/Q and IRM	HMC520LC4	HMC521LC4	HMC521LC4	HMC522LC4	HMC523LC4	HMC523LC4	HMC524LC4	HMC524LC4	HMC404
Voltage Variable Attenuator	HMC346LP3	HMC346LP3	HMC346LP3	HMC346LC3B	HMC346LC3B				
Multiplier: Passive X2	HMC189MS8	HMC189MS8	HMC204MS8G	HMC204MS8G	HMC204MS8G	HMC205	HMC205	HMC331LC3B	HMC331LC3B
Multiplier: Active X2	HMC368LP4	HMC368LP4	HMC368LP4	HMC368LP4	HMC448LC3B	HMC448LC3B	HMC448LC3B	HMC449LC3B	HMC449LC3B
Multiplier: Active X4		HMC443LP4	HMC370LP4	HMC370LP4					
Divide-by-2	HMC361S8G	HMC364S8G	HMC492LP3	HMC492LP3	HMC492LP3				
Divide-by-4	HMC362S8G	HMC365S8G	HMC493LP3	HMC493LP3	HMC493LP3	HMC447LC3	HMC447LC3		
Divide-by-8	HMC363S8G	HMC363S8G	HMC494LP3	HMC494LP3	HMC494LP3				
VCO & PLO: *Requires X2 or X4	HMC466LP4 HMC506LP4	HMC513LP5 HMC514LP5	HMC401QS16G HMC529LP4	HMC535LP4 HMC529LP4	HMC429LP4*	HMC533LP4 HMC431LP4*	HMC515LP5*	HMC531LP5*	HMC505LP4* HMC512LP4*

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### EUMW 2005: A SOPHISTICATED SUCCESS

aute cuisine, chic cafés, restaurants and, of course, fine wines are the sta-■ ple diet for Parisians. Last October, however, the city also served up a mouth-watering array of technology and innovation as the 8th European Microwave Week was staged at the CNIT La Défense, International Conference and Exhibition Centre. The event made every effort to satisfy the appetite of its global attendees and visitors, hungry to hear about and discuss new developments, view the latest products, and take the opportunity for professional and personal networking. There was also the opportunity to taste the delights of a sophisticated, cosmopolitan and hospitable city. Even a less than hospitable national one-day industrial strike did little to dampen spirits with the microwave community proving its resilience.

That resilience has been evident in recent years as the industry has had to cope with depressed markets in certain sectors and uncertainty in others. Confidence has been rebuilt slowly but surely. EuMW 2005 played a vital role in boosting this confidence by focusing on the commitment and drive being channelled into technologi-

cal and product development, and by highlighting the positive efforts being made. That the Week had such an impact is a tribute to the prolonged dedication and endeavour of EuMW general chairman, Raymond Quéré; secretary, Michèle Lalande, treasurer, Bernard Jarry and their associates at GAAS® - chairman, Robert Plana; ECWT - chairman, Serge Toutain; EuMC – chairman, Jean-Louis Cazaux and EuRAD – chairman, Joseph Saillard. During the year they have been supported by countless people, including local organisers, the TPC-members, the members of the review boards, the organizers of the workshops, short courses and special sessions, and the members of the EuMA Board of Directors. Horizon House Publications played its part, organizing the European Microwave Exhibition, running the registration system, liaising with the venue and contributing to the organisation of the conferences. Invaluable as always were the many industrial companies and organisations that lent their financial and practical support.



RICHARD MUMFORD Microwave Journal European Editor

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#### AMPLIFIERS - Wideband LNA, PA & Drivers and >10 Watt PA Modules

Frequency (GHz)	Function	Gain (dB)	OIP3 (dBm)	NF (dB)	P1dB (dBm)	Bias Supply	Part Number
2 - 20	Wideband LNA	15	24	2.2	14	12V @ 65mA	HMC-C001
2 - 20	Wideband LNA	14	26	2	18	12V @ 60mA	HMC-C002
<b>NEW!</b> 7 - 17	Wideband LNA	22	25	2.5	14	+8V @ 93 mA	HMC-C016
NEW! 17 - 27	Wideband LNA	18	25	3	14	+8V @ 96 mA	HMC-C017
2 - 20	Wideband PA	15	34	4	26	12V @ 310mA	HMC-C003
NEW! 2 - 20	Wideband PA	30	30	2.5	26	+12V @ 400 mA	HMC-C026
0.01 - 20	Wideband Driver	16	33	3	23	12V @ 195mA	HMC-C004
<b>NEW!</b> 0.4 - 1.0	10 Watt PA	40	50	13	40	+12V @ 6.6A	HMC-C012
NEW! 0.8 - 2.0	10 Watt PA	40	50	11	40	+12V @ 6.6A	HMC-C013
1.8 - 2.2	15 Watt PA	42	53	6	42	+14V @ 6.5A	HMC-C008



#### FREQUENCY DIVIDERS (PRESCALERS)

Input Freq. (GHz)	Function	Input Power (dBm)	Output Power (dBm)	100kHz SSB Phase Noise (dBc/Hz)	Bias Supply	Part Number
DC - 18	Divide-by-2	-15 to +10	-4	-150	+5V @ 75mA	HMC-C005
DC - 18	Divide-by-4	-15 to +10	-4	-150	+5V @ 93mA	HMC-C006
DC - 18	Divide-by-8	-15 to +10	-4	-150	+5V @ 98mA	HMC-C007



#### MIXERS - Double-Balanced & I/Q Mixers

Fi	RF req. (GHz)	Function	IF Freq. (GHz)	Conv. Gain (dB)	LO/RF Isol. (dB)	IIP3 (dBm)	Part Number
NEW!	4 - 8.5	I/Q Mixer	DC - 3.5	-7.5	40	23	HMC-C009
NEW!	16 - 32	+13 LO, DBL-BAL	DC - 8	-8	28	19	HMC-C014
NEW!	24 - 38	+13 LO, DBL-BAL	DC - 8	-8.5	35	20	HMC-C015



#### PHASE SHIFTERS - Analog

Frequency	Function	Insertion	Phase	2nd Harmonic	Control Voltage	Part
(GHz)		Loss (dB)	Range (Deg)	Pin= 0 dBm (dBc)	Range (Vdc)	Number
6 - 15	Analog	7	750° @ 6 GHz	40	+0V to +5V	HMC-C010

#### **SWITCHES**

Frequency	Function	Insertion	Isolation	Input	Control	Part
(GHz)		Loss (dB)	(dB)	P1dB (dBm)	Input (Vdc)	Number
DC - 20	SPDT, Hi Isolation	2.0	50	23	CMOS	HMC-C011

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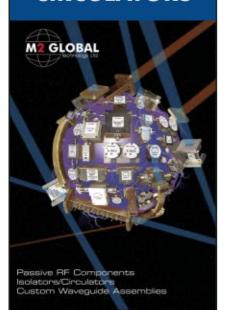
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#### THE CONFERENCES

The four separate but complementary conferences — GAAS®2005, the European Gallium Arsenide and other Compound Semiconductors Application Symposium; the European Conference on Wireless Technology (ECWT 2005); the 35th European Microwave Conference (EuMC 2005) and the second European Radar Conference (EuRAD 2005) were supported and enhanced by a variety of dedicated workshops, short courses and tutorials, focusing on specific, up-to-the-minute topics in the field of microwave technologies.

#### **GAAS®2005**

Papers were submitted from 25 countries, covering a broad spectrum of topics in the area of RF and microwave electronic devices and circuits. The result was a conference that featured more than 90 oral presentations in 18 sessions and four workshops and short courses. Focused sessions were organised that addressed activities in two EU Networks of Excellence as well as on new emerging technologies such as GaN and NanoCMOS. There were also sessions on 3D MCM modules for space applications, microwave and mm-wave ICs in silicon technology. Significantly, too, there was a session dedicated to industrial aspects, featuring invited speakers from industry and an industrial round table panel session.



#### **PRIZES AND AWARDS**

As always there was fierce competition for the prizes given to the best papers and the Fellowship awards. The €1,500 Alcatel Alenia Space Prize was won by Koli Yamanaka from the Mistsubishi Electric Corp. R&D Centre, Kamakura, Japan. Awarded with the WIN Semiconductors prize of €1,500 was Rachid Driad from the Fraunhofer Institute of Ap-

plied Solid State Physics, Freiburg, Germany. Elisra awarded €1,500 to Sanghyun Seo from Technische Universität Darmstadt, Germany, while the UMS Prize of €1,500 went to Jean Godin from the Alcatel-Thales III-V Lab, Marcoussis, France. To encourage the youth and invest in the future, four €3,000 Young Research Fellowships were awarded to: Antonio Raffo from the University of Ferrara, Italy; Masoud Movahhedi of AmirKabir University of Technology, Tehran, Iran; Krishnamurthy Lokesh from the University of Manchester, UK; and Vikas Manan of the University of California, Santa Barbara, US. A fifth Fellowship of €3,000 was shared by Rocco Giofrè and Antonio Nanni of the University of Rome Tor Vergata, Rome, Italy.

#### **ECWT**

The conference is an international forum for the presentation and discussion of the latest developments in the field of wireless communication technologies. To underline that fact, 136 papers, submitted by authors from 25 countries, were presented during the 16 oral sessions and two poster sessions. In the opening and closing sessions, keynote speakers provoked keen discussion when addressing the present trends in the wireless communications field. Seven sessions were co-organised with the European Microwave Conference, together with a focused session on Wireless Personal Area Networks.

#### **PRIZES**

The ECWT Best Paper Prize was won by David Marchaland from ESIEE-ESYCOM/STMicroelectronics, France, while the ECWT Young Engineers Prize went to Georg Strasser of LMC, Austria.

#### **EuMC**

There was a significant rise in the number of submissions compared to previous years. There were 53 regular oral sessions, including three focused sessions on specific topics and 16 joint sessions with the other three conferences. Special emphasis was given to the activities of the different Networks of Excellence and there were lunchtime poster sessions each day in the European Microwave Exhibition hall.

## ATTENUATORS

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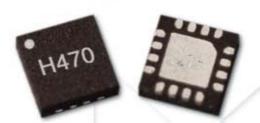
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	HMC468LP3	3 Bit	DC - 6	1 to 7	+50	
NEW!	HMC540LP3	4 Bit	DC - 5.5	1 to 15	+50	
NEW!	HMC470LP3	5 Bit	DC - 3	1 to 31	+45	
NEW!	HMC271LP4	5 Bit, Serial Control	0.7 - 3.7	1 to 31	+48	
	HMC273MS8G	5 Bit	0.7 - 3.7	1 to 31	+48	
NEWI	HMC305LP4	5 Bit, Serial Control	0.7 - 3.8	0.5 to 15.5	+52	7
NEW!	HMC539LP3	5 Bit	DC - 4	0.25 to 7.75	+50	
	HMC306MS10	5 Bit	0.7 - 4.0	0.5 to 15.5	+52	
NEW!	HMC472LP3	6 Bit	DC - 3	0.5 to 31.5	+45	
	HMC425LP3	6 Bit	2.4 - 8.0	0.5 to 31.5	+40	
	HMC424LP3	6 Bit	DC - 13.0	0.5 to 31.5	+32	

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766 San Aleso Ave., Sunnyvale, CA 94085 Tel: (408) 541-9226/Fax: (408) 541-9229 E-mail: Cernex@cernex.com Demonstrating that it has become a truly international conference, there was a dramatic rise in interest from Asia, with South Korea leading all other countries, including France, the host country. From the Middle

East to Far East Asia, North and South America, Africa, Oceania, Eastern and Central Europe, there were contributions from 49 countries.

#### **PRIZES**

The €5,000 EuMC Prize awarded by the EuMA for the best paper presented at the conference went to Hiroshi Murata, Kazumasa Kaneda, Akira

Enokihara and Yasuyuki Okamura from Osaka University and Matsushita Electric Industrial Co., Japan. Two €2,000 Young Engineers Prizes were awarded. They went to Stefan Mueller of Technische Universität Darmstadt, Germany, and Alessandro Ocera from the University of Perugia, Italy.

#### **EuRAD**

Building on the success of the first European Radar Conference in Amsterdam last year, EuRAD 2005 received an increased number of high level papers with contributions from many countries. It encompassed a wide range of topics, including radar devices, systems and processing techniques. Within the conference framework radar and radar related researchers were given the platform to present their progress and offer new insights during oral and poster sessions as well as two focused sessions, one workshop and one short course.

#### **PRIZES**

Two prizes sponsored by Raytheon were awarded by the EuRAD TPC and the General Assembly of the EuMA. The European Microwave Association Radar Prize of €3,000 was awarded to D. Cerutti-Maori, et al., FGAN-FHR/ARB, Wachtberg, Germany. To encourage the student fraternity, the €2,000 European Radar Conference Young Engineer Prize

went to J.C. Diot, et al., Université de Limoges, France.

#### THE EXHIBITION

Paris is renowned as being the centre of the world's fashion industry



but it was the microwaves and RF, wireless technologies, semiconductor and radar communities that took centre stage at the CNIT. And just as the top designers use the Paris catwalks to show off their latest creations, the European Microwave Exhibition provided a stage for companies from across the globe to showcase their wares. Indeed, some used it to launch brand new products or show their latest creations for the very first time. Read on to discover the stars of the RF and microwave winter collection and get an insight into future trends as the key products paraded at the show are highlighted; apologies to those companies that have not been mentioned due to space constraints.

Test and measurement crosses the boundaries of the different industry sectors that EuMW embraces, so it is no surprise that manufacturers in the field are particularly active, targeting the event for new product introductions.

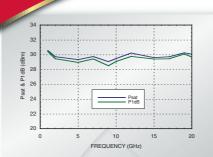
That is definitely the case for Agilent Technologies, which made a number of key announcements. Particular emphasis was given to the new low cost compact spectrum analyzer (CSA), which is the first in a series of intuitive, low cost spectrum analyzers that enable technicians, R&D and manufacturing engineers to make complicated RF measurements with speed, ease and confidence. The company also chose to demonstrate

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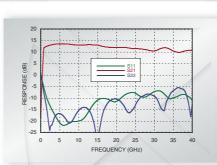




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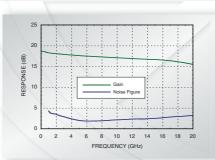




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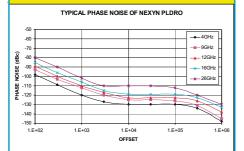
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Also introduced were two additional models to the N6030A series arbitrary waveform generator (AWG) family. The N6032A, a dual-channel AWG designed for radar and military communications, delivers 625 MS/s and 15 bits of vertical resolution per channel to create wideband waveforms up to 250 MHz wide. The N6033A generator, designed for satellite communications and general-purpose wideband applications, delivers 625 MS/s and 10 bits of vertical resolution per channel.

Sharing the Agilent stand and similar ambitions to develop significant products, Cascade Microtech launched its WinCal 2006 software to address the testing challenges brought on by the increase in the volume of complex, high speed semiconductors that are designed and tested for use in mobile communications products.

The software is designed to provide an easy and successful path for RF wafer testing for the experienced engineer or those new to RF device characterization. It solves a wide variety of common problems including data correlation, training of new users, obtaining correct calibration coefficient definitions, calibration verification, erroneous use of untrimmed or non-50  $\Omega$  loads, and determining the source of unexpected or suspect measurement data.

Proving that they too can be prolific in the test and measurement arena.

Rohde & Schwarz introduced a plethora of new products. The focus was on the new family of network analyzers, all of which have the same operating concept and a common remotecontrol command The R&S set. ZVA24 analyzer is the high end model. It is available as a two-port and fourport version and

covers a frequency range from 10 MHz to 24 GHz. It has a dynamic range of more than 145 dB and a measurement speed of 3.5 µs per measurement point. The R&S ZVB20 network analyzer targets the medium price segment with high measurement speed, a wide dynamic range of more than 130 dB and maximum output power of up to +13 dBm.



The R&S ZVT8, the world's only eight-port network analyzer, features true multi-port architecture and offers very short measurement times while maintaining high measurement accuracy and a wide dynamic range. Also showcased was a complete measurement solution for WiMAX signals, a versatile spectrum analyzer and a compact measurement system for determining electromagnetic susceptibility.

For Ansoft, three products made their European debut. First, the Q3D Extractor v7 is a 3D quasi-static electromagnetic parasitic extraction tool. New features have been introduced that make it easier and more reliable for engineers to import 3D CAD models and integrated circuit, printed circuit board and package layouts from third-party tools. A new fault-tolerant meshing algorithm has been

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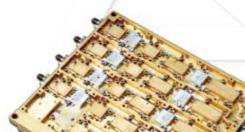






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   2010A & 2017S
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- High Temp Burn-In & Life Test
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added to make the meshing process tolerant to anomalies that occur in geometric data from CAD/EDA software programs.

Second, HFSS v10 is the new release of the company's flagship high frequency/high speed electromagnetic design product, introducing new capabilities for design-flow efficiency that allow users to easily share CAD models and results across existing CAD/CAE products. Finally, the Turbo Package Analyzer v4.2 is the latest version that combines new bidirectional integration with Synopsys' Encore package-design software with the company's 3D electromagnetic simulation. It enables full parasitic extraction of complex IC packages, such as ballgrid arrays.

Keeping up the interest, Anritsu made two major announcements. The first being pulse modulation enhancements to the company's MG3690B signal generators for more precise and convenient simulation of pulsed signals used in civilian and military radar applications.

These enhancements provide more narrow-leveled pulses, increased resolution when using the internal pulse generator and include higher frequency internal waveform generators to simulate modulated signals. The signal generator's pulse modulation performance responds to emerging needs of radar systems, especially those operating in the 1 to 2 GHz L-band.

The second is the launch of two wideband peak power meters, the single sensor input ML2495A and the dual sensor input ML2496A, which are designed for the demands of the rapid rise time radar measurement and the latest 4G wireless applications. The ML2490A series has been designed with a 65 MHz mainframe bandwidth and displays a typical rise time of 8 ns with 1 ns resolution when used with the company's new MA2411B pulse sensor. The ML2490A measures the peak, average and crest factor of both the continuous OFDM and framed OFDM, and is suitable for WLAN and WiMAX applications.

EuMW 2005 saw APLAC Solutions exhibit in its own right for the last time, following its recent acquisition by Applied Wave Research. However, it was made evident that its input will be very much in evidence in the future. More immediately, AWR announced a robust, featurepacked 2006 version of its flagship product, Microwave Office design suite. This latest version offers a new integrated filter synthesis solution using Nuhertz Technologies' filter synthesis technology. This feature offers complete synthesis capability for passive, transmission line, active, switched capacitor and digital filters, as well as two graphical user interfaces, one for the power user who requires advanced options and capabilities, and one for the mainstream user who needs ease-of-use. This latest development together with other key updates ensures that the design suite continues to deliver key productivity improvements to microwave designers, shortening design cycle time and speeding time-to-market for RF/microwave products.

Centre stage on the Aeroflex stand was taken by a new test capability, the PN95-DSM digital spectrum monitoring (DSM) option that has been added to the expanding PN9500 phase noise test system. The DSM option allows the user to view the spectrum of a signal in the same way as a spectrum analyzer and also integrates specific processes that are ideal for radar testing. The PN95-DSM measures power level, power variation, adjacent channel power and harmonic distortion, and more measurements are possible by setting markers. The company also showed the PN9276 microwave down converter, which has had its frequency boosted to 50 GHz to enable phase noise testing for higher frequency applications.

Now very much a key contributor to the Week is the Microwave Innovation Group, which showcased its WASP-NET and previewed Version 6.1, the enhanced features of which will include dielectric resonator filters, dielectric loaded horns, horns with shaped subreflectors, ridged waveguide slot arrays, LTCC filters and diplexers, extended combline elements, advanced broadband OMT elements, 3D black box elements,



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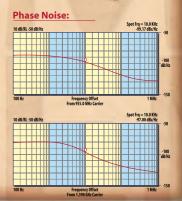
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Staying with German companies, Computer Simulation Technology previewed the CST Microwave Studio 2006. This time domain 3D EM simulator features a major redesign of the architecture, together with substantial new functionality. Most significant is the use of the CST Design Environment as a common access point to the company's solver technology. Structures are presented in 3D and schematic views and the comparison of models and co-simulation is facilitated by a new multi-document interface. No more details could be given as the product was still being developed but that can now be remedied by turning to the Product Feature on page 150 for the full story.

Not test and measurement but still focusing on the German companies, Antennessa launched two products. First, the INSITE box is an RF EMF monitoring station. Remotely operated, it makes on-going isotropic and selective measurements in twelve frequency bands: FM, TV3, TETRA,

TV4&5, GSM Tx and Rx, DCS Tx and Rx, DECT, UMTS Tx and Rx, and WiFi. Second, the company completes its range of EMF measurement systems with EME GUARD, a new alarm dosimeter developed to protect workers from the risks associated with RF electromagnetic fields.

Moving over the border and to the EuMW host country, France, OMMIC targeted the show to introduce a new range of products to include six-bit phase shifters, six-bit attenuators and complete integrated core chips at X- and C-band. These products take advantage of OMMIC's 0.18 µm enhancement-depletion technology that allows for the complete integration of functions. The first products include CGY2170UH and CGY2175UH.



which are fully integrated 'core chip' functions for phase array radar at X-and C-band, respectively.

As for the Italian representation, ABF Elettronica presented a 7/8 GHz duplexer, which is particularly suited to high capacity digital radio applications in outdoor units and is an alternative to the dielectric resonator approach. Important features are low cost, high reliability, quick frequency tuning, good performance and compactness. Characteristics include tunability frequency ranges of 7.1 to 7.4 GHz, 7.4 to 7.7 GHz, 7.7 to 8.1 GHz and 8.1 to 8.5 GHz. It has six resonators and an operating temperature range of –33° to +70°C.

Demonstrating the significant global impact of the exhibition, several non-European companies took the opportunity to launch new products. For instance, Peregrine Semiconductor unveiled the next generation of its UltraCMOS™ process technology. The first devices to be released on the company's HaRPTM-enhanced UltraCMOŚTM process are the PE42672 SP7T and the PE42660 SP6T RF switches for quad-band GSM and GSM/WCDMA handset applications. The former is said to be the world's first monolithic SP7T switch with an on-board CMOS decoder. This highly integrated solution simplifies and lowers the cost of RF designs by reducing overall part count by as many as six devices and 13 wire bonds. The PE42660 switch is drop-in compatible with the PE4263 GSM handset switch that was released at the end of 2004.

Similarly, TriQuint Semiconductor debuted four new high performance wideband millimetre-wave amplifiers





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	ZRL-400	150-400	30.0	2.5	42	25.0	12	575	119.95
	ZRL-700	250-700	29.0	2.0	46	24.8	12	575	119.95
	ZRL-1150LN	650-1400	31.0	0.8	40	24.0	12	500	119.95
	ZRL-1200	650-1200	27.5	2.0	46	24.3	12	575	119.95
	ZRL-2150	950-2150	25.0	1.5	33	22.0	12	300	119.95
	ZRL-2300	1400-2300	23.5	2.5	42	24.6	12	575	119.95
	ZRL-2400LN	1000-2400	27.0	1.0	45	24.0	12	550	139.95
NEW	ZRL-3500	700-3500	24.0	2.5	44.5	24.0	12	575	139.95

\*Internally voltage regulated for 6.5 to 17VDC input voltage range. Dimensions: (L) 3.75" x (W) 2.00" x (H) 0.80"

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with industry leading power bandwidth performance. The TGA4521 is a wideband millimetre-wave driver amplifier covering the 32 to 45 GHz frequency range, that features +25 dBm saturated output power and +24 dBm, 1 dB compressed output power. The TGA4522 is a balanced version of the TGA4521, offering a higher output power capability with +27.5 dBm saturated and +27 dBm, 1 dB compressed performance at 38 GHz.

The TGA4046 is a balanced high power amplifier MMIC for Q-band applications, particularly military and commercial satellite uplink communications with a saturated output power of +33 dBm and 1 dB compressed power of +32 dBm. Finally, the TGA4040 is a medium power amplifier/frequency multiplier MMIC for a variety of applications including military and commercial satellite communications, electronic warfare, digital radio and instrumentation.

Illustrating the diversity of the products on display, Analog Devices has extended its portfolio of leading RFICs with the ADF7020-1 trans-

ceiver. Designed to address short range device (SRD) wireless connectivity applications in home and building automation, wireless video and audio, automatic wireless metering and security applications, the transceiver is a single-chip solution for the 135 to 650 MHz frequency range with good co-channel and adjacent

channel rejection. The transceiver supports data rates of 0.15 to 200 kbits/s frequency shift keying and 0.15 to 64 kbits/s amplitude shift keying. The device operates on a +2.3 to +3.6 V power supply with programmable output power from -16 to +13 dBm in 0.3 dBm steps.

This product round up began with Agilent and will finish with it too in the guise of Agilent Semiconductor Products, which announced the ex-



pansion of its family of millimetrewave integrated circuits to include low cost, surface-mount amplifiers operating in the 20 to 40 GHz frequency range. The new product family consists of seven devices. The AMMP-6231 is a high performance, low noise amplifier ideally suited for 18 to 31 GHz receive chains. The AMMP-6345 and AMMP-5040 are driver amplifiers for 20 to 45 GHz broadband applications. The AMMP-5024 is a travelling-wave amplifier operating from 100 kHz to 40 GHz. Two others, AMMP-6425 and AMMP-6430, are high performance, 1 W power amplifiers for use in frequencies from 17 to 33 GHz. Finally, the AMMP-6130 is a frequency multiplier with an integral driver amplifier operating in the 30 GHz satellite band.

#### **SOCIAL EVENTS**

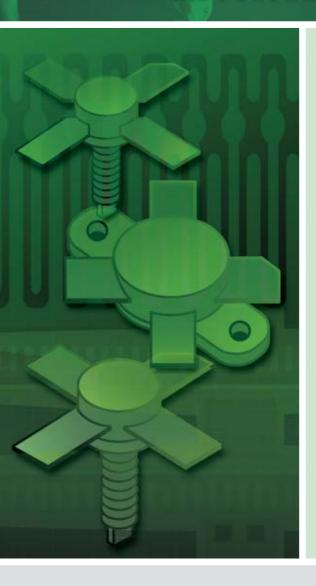
The extracurricular activities that are organised are just as important as the academic and have become an integral part of the Week. On Monday evening, guests of the GAAS Association enjoyed the traditional GAAS Dinner, but at a typically chic location, in a restaurant located on the fifth floor of the famous La Samaritaine store in the historical heart of Paris, with a splendid view of the city.

It was more the exchange of views that the EuMW 2005 Welcome Reception, sponsored by Agilent, EuMA and Horizon House, provided as it accomplished the difficult feat of bringing together the registered conference delegates from all four conferences and the exhibitors participating in the show, thus providing academics with the rare opportunity to exchange





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2N5946	MRF141G	MRF1946A	MRF652S
2N6081	MRF166	MRF221	TDS595
2N6084	MRF166C	MRF429	TPV595A
2N6985	MRF171	MRF448	
	MRF172	MRF450	

#### SD REPLACEMENTS

SD1013-03	SD1224	SD1274-01	SD1732
SD1015-06	SD1224-02	SD1407	TH430
SD1018	SD1224-10	SD1414	TH596
SD1143	SD1252	SD1446	TH597
SD1143-01	SD1253	SD1457	TH598
SD1143-03	SD1272	SD1490	UTV8100B
SD1146	SD1274	SD1726	

#### MS REPLACEMENTS

MS1000	MS1253	MS1426	MS1512
MS1001	MS1281	MS1501	MS1537
MS1226	MS1401	MS1502	MS1579
MS1227	MS1403	MS1503	

#### BL REPLACEMENTS

BLF522         BLV10         BLW76         BLX5           BLU99         BLV21         BLW77         BLX5           BLU99SL         BLV31         BLW86	
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ideas with those who actually turn the theory into practice. On Wednesday evening, attendees realized that life does not get much better as they were treated to a Gala Cocktail Evening combined with a trip on the Seine to savour the historical heart of Paris.

#### **SPONSORS**

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An interesting and challenging conference, allied to an exhibition

that attracts the leading global players are the key ingredients of a successful event, but it is the added extras that gives the Week its own memorable and unique flavour. That can only be achieved with the support and encouragement of commercial sponsors, many of which have made specific features their own in recent years. That is the case with Platinum Sponsors Agilent, whose contribution to the Welcome Reception has made it a social highlight. Thanks also to Ansoft for the delegate bags, WIN Semiconductors for the badge cords and Mician for the visitor bags. Welcome sustenance was provided during the coffee breaks, which were sponsored by Ansoft, Mimix, AEP, Micrometrics and Ultrasource, while the two Cyber Cafés sponsored by CST provided an intellectual caffeine boost and the opportunity to visit (among others) the EuMW web site with its Rohde & Schwarz sponsored banner. Rohde & Schwarz also played a vital part in the conference preparations with their all-important support of the TPC dinner. And finally, those who attended the event would not have missed the Tektronix footsteps, which combined practicality with humour.

#### **MANCHESTER 2006**

It's a new venue, a new city and an extended format as the G-Mex/MICC Complex in Manchester, England, plays host to the 9th European Microwave Week, over six days, on 10 to 15 September 2006. The microwave community should feel at home in the world's first industrial city, which boasts a wealth of historical and modern attractions, together with a plethora of restaurants, pubs and bars as well as the Manchester United Football Club, of course. As for the event itself the organisational team is in place, with the goal of providing four strong, responsive and challenging conferences, complemented by a healthy exhibition featuring international players and an attractive and vibrant social agenda.



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# PERFORMANCE COMPARISONS BETWEEN DIELECTRIC RESONATOR ANTENNAS AND PRINTED MICROSTRIP PATCH ANTENNAS AT X-BAND

The performance of a cylindrical dielectric resonator antenna (DRA) and a circular printed microstrip patch antenna (MPA) are compared at X-band. Comparisons between the antenna sizes, transmission coefficients, radiation patterns, gains and radiation efficiencies are discussed. Similar broadside radiation modes are excited for both antennas. The antennas are fabricated or etched on the same dielectric materials and designed with the same matched frequency range. It is concluded that the DRA has a wider bandwidth and a higher gain than the MPA. The radiation efficiency of the DRA is nearly 95 percent, while it is only approximately 80 percent for the MPA, due to the conduction losses.

icrostrip patch antennas (MPA)<sup>1–5</sup> and dielectric resonator antennas (DRA)<sup>6–7</sup> have been studied extensively. They share the advantages of low profile, lightweight, ease of fabrication and are easy to excite by different methods. Both antennas are viable candidates for numerous applications, either as individual elements or in an array environment. However, metallic and dielectric losses are usually associated with most MPAs when they are printed on dielectric substrates.<sup>3</sup> On the other hand, there is no metallic loss for the DRAs. Hence, they have the inherited advantage of higher radiation efficiency at high frequencies.<sup>7</sup> A comparison

between DRAs and microstrip patches was performed numerically.<sup>8</sup> The advantages of the DRA over the MPA were clear. Measurement of the radiation efficiency could be a means to compare the losses in the antennas. The conduction losses, dielectric losses and surface wave losses all contribute to lowering the radiation efficiency, which can be accurately measured by the Wheeler cap method.<sup>9–11</sup>

R. CHAIR, A.A. KISHK, K.F. LEE AND D. KAJFEZ University of Mississippi Oxford, MS

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In this article, the performance of a cylindrical  $DRA^{5,12-14}$  and a circular MPA<sup>15-18</sup> at X-band are studied experimentally. Both the DRA and MPA are excited by a coaxial probe and resonate at 9.9 GHz. The locations of the feeds are carefully chosen in order to excite the broadside radiation modes. The MPA is excited in the TM<sub>11</sub> mode and the DRA in the  $\text{HEM}_{11\delta}$  mode. In order to have a fair comparison, the MPA is printed

on the same dielectric material that is used to fabricate the DRA. The bandwidths for the DRA and MPA are 10.3 and 1.3 percent, respectively, with a dielectric constant of 10.2 used for both antennas. The antenna gain of the DRA is 1 dB higher than for the MPA. The Wheeler cap method is employed to measure the radiation efficiency. It is shown that the radiation efficiency for the MPA is 80 percent and 95 percent for the DRA. As expected, the conduction losses of the MPA reduced the radiation efficiency and the gain of the antenna in X-band.

#### **ANTENNA GEOMETRIES** AND MEASUREMENT SETUP

**Figure 1** shows the geometries of the cylindrical DRA and the circular MPA. Both antennas are designed to have a good match at approximately 9.9 GHz. The circular-shaped MPA has a radius  $r = 2.45 \text{ mm} (0.082 \lambda_0)$ and is printed on a dielectric substrate with a dielectric constant  $\varepsilon_r =$ 10.2 and a thickness t = 0.64 mm



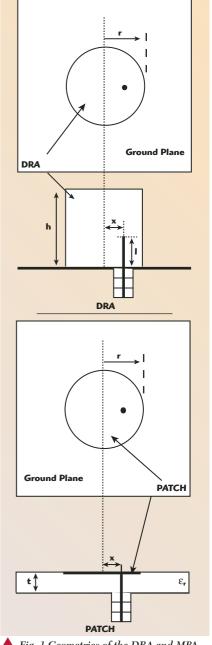


Fig. 1 Geometries of the DRA and MPA.



<b>VCO</b> Part Number	Frequency (MHz)	Vtune (Vdc)	Kvco (MHz/V)	Ø <sub>N</sub> @10KHz (dBc/Hz)	Output Power (dBm)	2nd Harmonic (dBc)	Pulling (MHz)	Pushing (MHz/V)	Vcc (Vdc)	lcc (mA)	Operating Temp (°C)
V150ME03	100 to 200	0 to 12.5		-111	7 ± 5	-10	(MHZ)	(MHZ/V)	12.0	(mA)	-40 to 85
						+					
V220ME01	200 to 239	0.5 to 4.5	14	-120	7.5 ± 2.5	-22	<0.5	<0.5	5.0	16	-40 to 85
CLV1277A	1213 to 1341	0.5 to 4.5	38	-108	2.5 ± 2.5	-15	<1	<1	5.0	22	-40 to 85
CRO2155A*	1960 to 2350	1 to 14	40	-106	7 ± 2	-10	<2	<0.5	6.0	27	0 to 85
CRO2780A*	2650 to 2910	0.5 to 15	20	-111	3 ± 3	-10	<0.5	<0.5	10.0	34	-40 to 85
CRO2880A	2760 to 3000	0 to 15	18	-110	12.5 ± 2.5	-20	<1	<1	10.0	29	-40 to 85
V950ME07	3900 to 6000	0 to 20	126	-80	4.5 ± 4.5	-14	<36	<14	5.0	21	-40 to 85
CRO4500A	4499 to 4501	0.5 to 4.5	12	-104	2 ± 2	-15	<1	<2	5.0	20	-20 to 70
PLL	Frequency	Step Size	Output Power	Ø <sub>N</sub> @ 10KHz	Ø <sub>N</sub> @ 100KHz H	2nd Harmonic	Ref Sup	Lock Time	Vcc	lcc	Operating Temp
Part Number	(MHz)	(kHz)	(dBm)	(dBc/Hz)	(dBc/Hz)	(dBc)	(dBc)	(msec)	(Vdc)	(mA)	(°C)
PCA1445C	1444 to 1446	1000	5 ± 2	-120	-140	-20	-59	3	5.0	40	-40 to 85
PCA1550A	1500 to 1600	1000	1.5 ± 2.5	-103	-124	-15	-70	3	5.0	40	-40 to 85
PSA2000C*	1970 to 2030	100	2 ± 2.5	-107	-128	-15	-70	2.5	5.0	30	-40 to 85
PCA3040C*	3040 to 3040		3 ± 3	-112	-132	-8	-60	1	5.0	35	-40 to 85
	3040 10 3040	1000	3 I 3	-112	-102	-0		-	3.0		
PSA3330C	3305 to 3335	125	0 ± 3	-106	-130	-12	-70	1	5.0	35	-40 to 85
PSA3330C PSA3500A								1 2			-40 to 85
	3305 to 3335	125	0 ± 3	-106	-130	-12	-70	-	5.0	35	

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858-621-2700 www.zcomm.com sales@zcomm.com  $(0.021~\lambda_0),$  where  $\lambda_0$  is the free space wavelength at 9.9 GHz. The  $TM_{11}$  mode is excited by an off center coaxial probe. The probe has a radius  $r_f$  = 0.3 mm and is off-centered in the MPA by x = 0.4  $\mu m$ . The cylindrical DRA has the following dimensions: r = 3.3 mm (0.11  $\lambda_0),~h=5.08$  mm (0.17  $\lambda_0),~\epsilon_r$  = 10.2,  $r_f$  = 0.4 mm, x = 2 mm and l = 2.54 mm. Both antennas are mounted on a square ground plane 30 by 30 mm (1  $\lambda_0 \times 1~\lambda_0).~A$ 

two-port HP8510C vector network analyzer (VNA) is used to measure the transmission coefficients. The measurement setup is shown in *Figure 2*. Port 1 of the VNA is connected to a reference MPA, which is identical to the MPA mentioned earlier, and Port 2 is connected to the DRA or MPA for comparison. The antennas, connected to Ports 1 and 2, are separated by a certain distance d between the two ground planes. The

measurement is taken when both antennas are facing each other. Since broadside modes are excited for both antennas, the maximum radiation is normal to the ground plane.

#### **MEASUREMENT COMPARISONS**

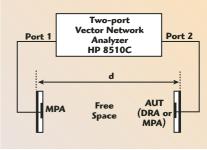
#### **Transmission Coefficients and Antenna Gains**

The measurement is made using the setup described in the previous section. The MPA is connected to Port 1, as a common transmitting antenna. The receiving port (Port 2 of the VNA) is connected to the antenna under test (AUT). First, the return losses of all the antennas are measured to ensure a good match at the desired frequency of 9.9 GHz. Figure 3 shows the return losses of the MPA and DRA. The resonant frequency for the DRA is 10.2 GHz. It has a matched frequency range from 9.75 to 10.81 GHz, with a 10.3 percent impedance bandwidth  $(S_{11} < -10 \text{ dB})$ . The MPA has a minimum return loss of -25 dB at 9.9 GHz. Its impedance bandwidth is 1.3 percent with a matched frequency range from 9.87 to 9.99 GHz. The comparison is performed at 9.9 GHz, which shows a good match ( $S_{11} < -13 \text{ dB}$ ) for both antennas.



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 $\triangle$  Fig. 2 Setup for measuring  $S_{21}$ .

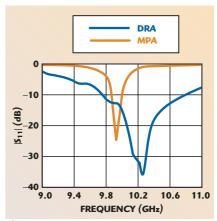


Fig. 3 Return losses of the DRA and

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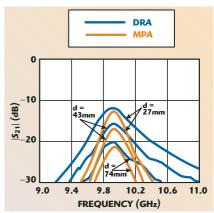


The transmission coefficients were measured with both antennas separated by a distance  $d=27~mm~(0.9~\lambda_0),\,43~mm~(1.43~\lambda_0)$  and 74 mm (2.47  $\lambda_0).$  These distances were chosen to have the antennas placed within both the Fresnel region (18.6 mm < d < 60 mm) and in the far field region (d > 60 mm). The measured transmission coefficients  $S_{21}$  are shown in  $\emph{Figure 4}.$  The transmission coefficients for the DRA are found to be  $-11.8~dB,\,-15.7~dB$  and

-20.4 dB when d = 27 mm, 43 mm and 74 mm, respectively. When the MPA is connected, the transmission coefficients are found to be -12.8 dB, -16.6 dB and -21.5 dB at d = 27 mm, 43 mm and 74 mm, respectively. The power received by the DRA is always 1 dB higher than by the MPA, at 9.9 GHz. In addition, the Q-factor of the DRA is found to be lower than the MPA, which leads to the transmission coefficient levels of the DRA dropping at a slower

rate than for the MPA. The percentage increase of the power received by the DRA compared to the MPA is shown in **Figure 5**. The 1 dB differences between the DRA and MPA is equivalent to about 25 percent more power received/transmitted by the DRA than by the MPA, with the same input power. The matching of the MPA deteriorates quickly due to its narrow bandwidth, when the MPA will no longer receive or radiate the signal efficiently. It is noted that the percentage differences of the power received by the DRA and MPA grows quickly when the frequency is below or above 9.9 GHz. The same characteristics are found for different distances d. The percentage increase in the receiving power by the DRA is mainly due to the mismatch of the MPA.

A similar test was also performed in the far field range, inside an anechoic chamber. A standard gain horn from Narda Microwave was used as the transmitting antenna. The AUT was located two meters away from the transmitting horn. The average



ightharpoonup Fig. 4 Measured  $S_{21}$  for the DRA and MPA

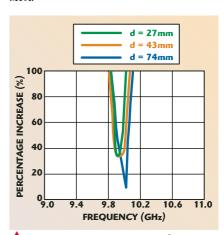
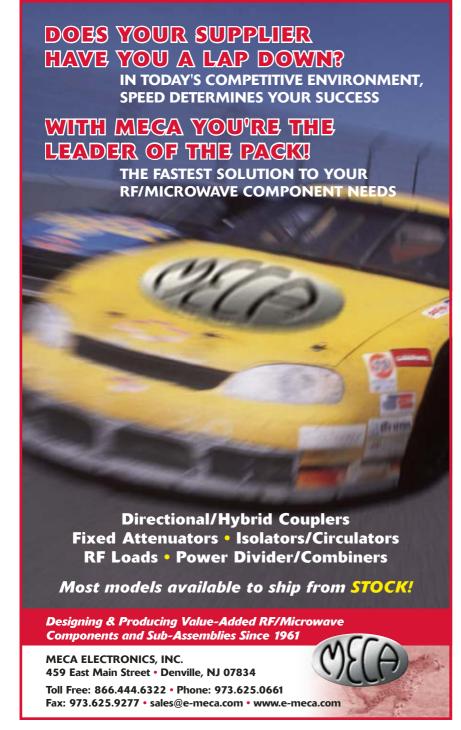


Fig. 5 Percentage increase in the power received by the DRA compared to the MPA.





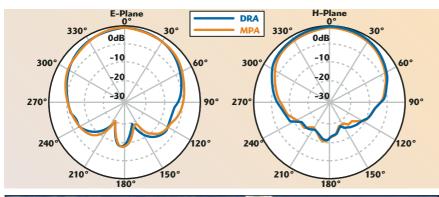
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Fig. 6 Radiation patterns of the DRA and MPA.

gains of the DRA and MPA, measured in the broadside direction, were 7.7 and 6.7 dBi, respectively.

#### **Radiation Pattern**

The radiation patterns of both the DRA and MPA were measured at 9.9 GHz. With the off-center probe excitation, the HEM<sub>11δ</sub> and TM<sub>11</sub> broadside modes are excited in the DRA and MPA, respectively. The co-polar radiation patterns of both antennas are depicted in *Figure 6*. The DRA has a 3 dB beamwidth of 86° and 90° in the E- and H-plane, respectively. The MPA 3 dB beamwidth is 88° in the E-plane and 90° in the H-plane. It is noted that both antennas are radiating with similar beamwidth and front-to-back ratio.

#### **Radiation Efficiency**

The radiation efficiencies of both the DRA and MPA are measured by the Wheeler cap method. For accurate results, it is required that the antenna be enclosed by a conducting cavity, the Wheeler cap.9 A conducting cylindrical cap is used to shield the antenna. Since the antenna is prevented from radiation by the cap, the measured input resistance is equivalent to the loss resistance.<sup>11</sup> The radiation efficiency is defined by the ratio between the radiated power and the total input power. By computing the input resistance with and without the cap, the radiation efficiency can be found as

$$\eta_{rad} = \frac{P_{rad}}{P_{tot}} = \frac{R_{rad}}{R_{tot}} = \frac{R_{in} - R_{cap}}{R_{in}} \quad (1)$$

where

 $P_{rad}$ ,  $R_{rad}$ = radiated power and resistance

 $P_{tot}$ ,  $R_{tot}$  = total input power and resistance

R<sub>in</sub> = input resistance without the cap

R<sub>cap</sub> = input resistance with the

The measurement setup is shown in *Figure 7*. Using Equation 1, the radiation efficiency of the DRA and MPA at 9.9 GHz are measured to be approximately 95 and 80 percent, re-

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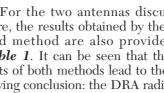
both the DRA and MPA are summa-

rized. The MPA occupies a smaller vol-

spectively. Both antennas have similar amounts of dielectric loss. The lower radiation efficiency of the MPA is mainly caused by the conduction losses. A second way<sup>18</sup> to measure the antenna efficiency by the Wheeler cap method is to determine the unloaded Q factor of both the radiating antenna, Q<sub>0rad</sub>, and the covered antenna,  $Q_{0cov}$ . The radiation efficiency at the resonant frequency is then computed as

$$\eta = 1 - \frac{Q_{0 \text{ rad}}}{Q_{0 \text{ cov}}} \tag{2}$$

For the two antennas discussed here, the results obtained by the second method are also provided in Table 1. It can be seen that the results of both methods lead to the following conclusion: the DRA radiation efficiency is 93 percent or higher, while the MPA radiation efficiency is 81 percent or lower.



### Wheeler Cap AUT $Z_{cap} = R_{cap} + R_{cap}$ AUT

**DISCUSSION** 

Fig. 7 Measurement setup for the Wheeler cap method.

#### **TABLE I** PERFORMANCE OF THE CYLINDRICAL DRA AND CIRCULAR MPA

	Cylindrica DRA	al Circular MPA
Radius (r) (mm)	$\begin{array}{c} 3.3 \\ (0.11 \lambda_0) \end{array}$	$\begin{matrix}2.45\\(0.082\lambda_0)\end{matrix}$
Height (total thickness) (h) (mm)	$5.08 \\ (0.17 \lambda_0)$	$0.64 \\ (0.021 \lambda_0)$
$\begin{array}{c} \text{Dielectric} \\ \text{constant} \ (\epsilon_{r}) \end{array}$	10.2	10.2 (substrate)
Resonant frequency $(f_0)$ (GHz)	9.9	9.9
Bandwidth (BW) (%)	10.3	1.3
Radiation mode	$\text{HEM}_{11\delta}$	$\mathrm{TM}_{11}$
$\begin{array}{c} Transmission\\ coefficient\\ (S_{21})(dB)\\ d=27\;\mathrm{mm}\\ d=43\;\mathrm{mm}\\ d=74\;\mathrm{mm} \end{array}$	-11.8 -15.7 -20.4	-12.8 -16.6 -21.5
3 dB beamwidth E-plane (°) H-plane (°)	86 90	88 90
Antenna gain (dBi)	7.7	6.7
Radiation efficiency (\eta_{rad}) Method 1 - from Equation 1 (%) Method 2 - from Equation 2 (%)	95	80 80.7 ± 0.3



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ume than the DRA. The MPA has a 50 percent smaller volume than the DRA, as well as a lower profile. The height of the DRA is eight times greater than the MPA. The matched bandwidth of the MPA is only 1.3 percent, but the DRA bandwidth is nearly eight times greater (10.3 percent). Both the DRA and MPA are excited with broadside radiating modes and the radiation patterns are nearly the same. By comparing the gain and the radiation efficiencies, it is

concluded that the conduction losses of the MPA causes the gain to be 1 dB lower than the DRA and the MPA has a radiation efficiency of only 80 percent.

#### CONCLUSION

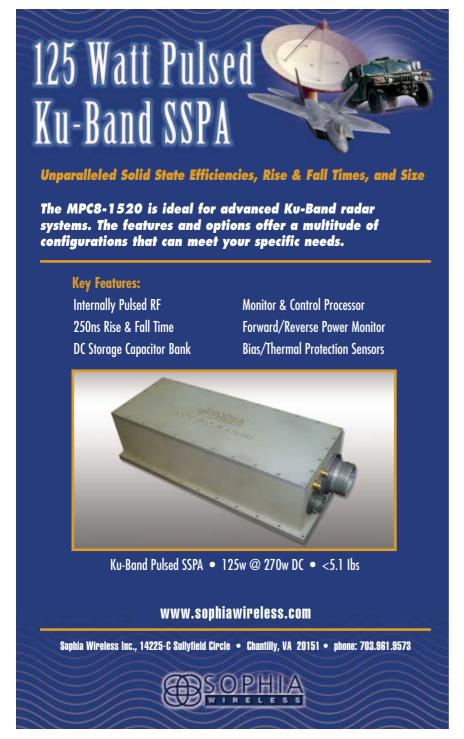
The performance of a cylindrical dielectric resonator antenna (DRA) and a circular microstrip patch antenna (MPA) were compared at X-band. The DRA, without conduction losses, was showing higher radiation efficiency than the MPA. The DRA had a 1 dB gain higher than the MPA. In addition, the matched bandwidth of the broadside-radiating mode of the DRA is 10 percent and only 1.3 percent for the MPA. Both antennas showed similar radiation patterns with similar beamwidth. However, the advantage of using MPA was its smaller volume.

#### **ACKNOWLEDGMENT**

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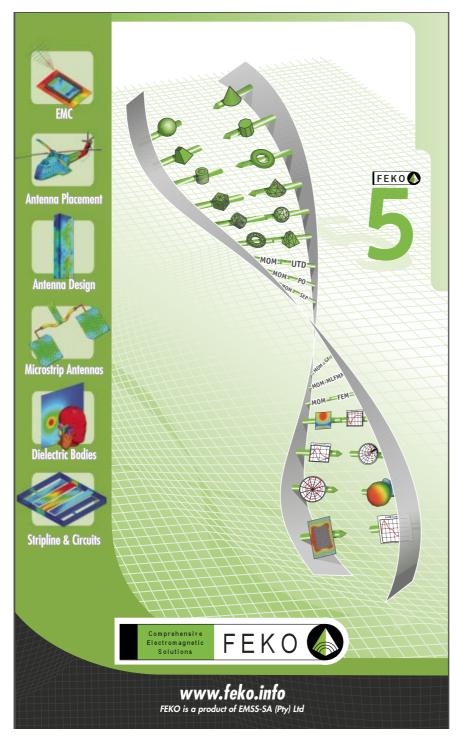
Kai Fong Lee received his BSc and MSc degrees from Queen's University, Canada, in 1961 and 1963, respectively, and his PhD degree from Cornell University in 1966, all in electrical engineering. He held research, teaching and administrative positions at various

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Darko Kajfez obtained his electrical engineer's degree (Dipl. Ing.) from the University of Ljubljana, Slovenia, in 1953, and his PhD degree from the University of California at Berkeley in 1957. He is currently emeritus professor of electrical engineering at the University of

Mississippi. His research interests include RF and microwave measurements and analysis.



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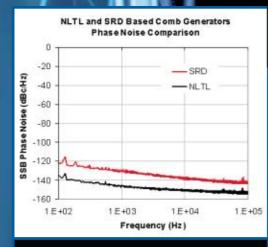
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## A PRINTED UWB TRIANGULAR MONOPOLE ANTENNA

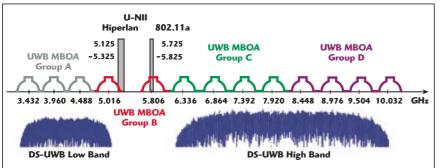
A planar printed triangular monopole antenna (PTMA) is presented for ultra-wideband (UWB) communications. The HFSS 3-D EM solver is employed for design simulation. A printed PTMA has been fabricated on a FR-4 substrate. The measured VSWR is less than 3 from 4 to 10 GHz. In the UWB communications frequency range, the measured phase distribution of the input impedance is quite linear and the H-plane patterns are almost omni-directional. The Kirchhoff's surface integral representation (KSIR) was adopted in the developed FDTD code to compute the far-field distributions from the near-field ones in the time domain. This is to investigate the radiated power spectral density (PSD) shaping to comply with the Federal Communications Commission (FCC) emission limit mask. The effect of various source pulses (first-order Rayleigh pulses with  $\sigma = 20$ , 30 and 50 ps) on the radiated PSD shaping is also studied.

he emerging ultra-wideband (UWB) radio is the technology for transmitting and receiving short, information-encoded, electromagnetic impulses. <sup>1,2</sup> UWB technology is loosely defined as any wireless transmission scheme that occupies a bandwidth of more than 25 percent of a center frequency, or more than 1.5 GHz. According to the Federal Communications Commission

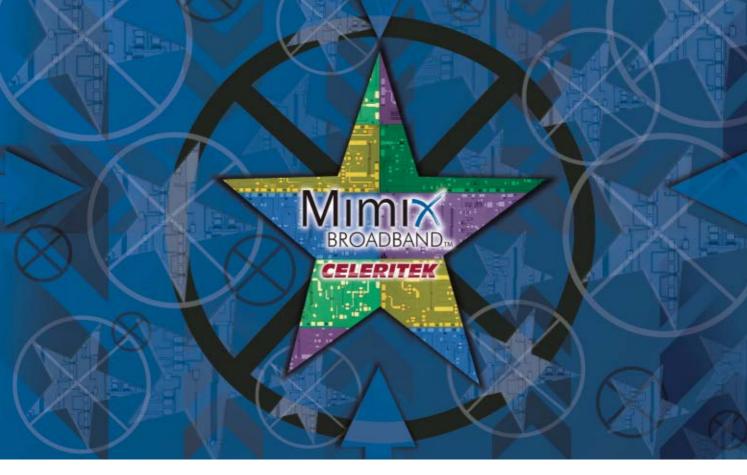
(FCC),<sup>3</sup> the frequency band of UWB (the category of communications and measurement systems) should be contained between 3.1 and 10.6 GHz. *Figure 1* shows the spectrum allocation of the current UWB system for multiband OFDM (MBOA) and direct sequence (DS) CDMA UWB. The MBOA has four groups (group A, B, C and D) and thirteen bands, each with a bandwidth of 500 MHz.

The DS-UWB system has a low band from 3.1 to 5.15 GHz and a high band from 6 to 10.1 GHz. Due to its extremely wide operating bandwidth, it could possibly interfere with other existing electronic systems operating at the same time. In

Fig. 1 Spectrum allocation for UWB communications.



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Image Reject	22IRM0324	20.0-28.0	10.0-15.0	DC-4.0	8.0	+16.0	+15.0
Image Reject	27IRM0339	27.0-38.0	12.0-20.0	DC-4.0	8.0	+15.0	+15.0
Image Reject	38IRM0363	32.0-42.0	15.0-23.0	DC-4.0	9.0	+14.0	+12.0
Balanced	XM1000	32.0-46.0	29.0-47.0	DC-3.0	7.0	+25.0	+15.0
Image Reject	XM1002	34.0-46.0	30.0-50.0	DC-4.0	8.0	+24.0	+12.0
Image Reject	40IRM0540	37.0-46.0	33.0-50.0	DC-4.0	12.0	+27.0	+15.0



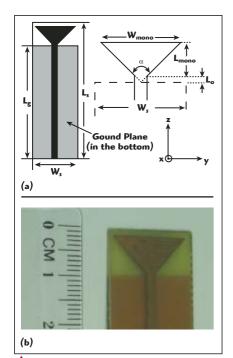


Fig. 2 Geometry and a realized printed PTMA.

order to make it compatible with existing narrow-band radio services, the maximum permissible effective

isotropic radiated power (EIRP) density is set as  $-41.3~\mathrm{dBm/MHz.^3}$  Hence, the emission limits of the radiated power are a critical consideration in UWB radio systems, especially for the antenna design.

In general, there are two ways to limit the radiated PSD shaping to conform to the standard mask set by the FCC:<sup>4</sup> the first is to design the antenna as a special filter to suppress the unwanted radiation outside the UWB band or, second, to select a source pulse in the specific band to let the radiated PSD meet the FCC required emission limits. In this article, the second approach is used. Here, a printed monopole-type antenna is adopted for the design of a broadband antenna for UWB application.<sup>5,6</sup> The design simulation, fabrication and measurements of a printed planar triangular monopole antenna (PTMA), fabricated on a FR-4 PCB, are reported. The HFSS 3-D EM simulator is employed for design simulation. The antenna input VSWR, the phase of the input impedance and the radiation patterns are presented. Also, an FDTD code, developed with

the Kirchhoff's surface integral representation (KSIR), is used to compute the time-domain far-field distribution. This is to investigate the radiated PSD shaping to comply with the FCC emission limit mask. First-order Rayleigh pulses with  $\sigma=20,\,30$  and 50 ps are used and the resulting PSD are compared.

#### **ANTENNA DESIGN**

In this article, a printed PTMA is developed, based on a triangular monopole antenna.<sup>5,6</sup> The structure of this antenna consists of a tapered radiating element excited by a suitable feedstructure, such as a coplanar waveguide (CPW) or microstrip line. As shown in Figure 2, the antenna geometry, the width, length and flare angle of the antenna are denoted by  $W_{mono},\,L_{mono}$ and  $\alpha$ , respectively. A 50  $\Omega$  microstrip line is used to feed the PTMA at the apex angle of the triangular patch. The distance between the end of the monopole and the terminal of the microstrip line is denoted by  $L_0$ . The antenna is printed on one side of a FR-4 substrate with a width W<sub>s</sub>, a length L<sub>s</sub> and a thickness T. On the other side of the substrate, a ground plane of width W<sub>s</sub> and length  $L_g$  is printed. The detailed parameters of the antenna are summarized in *Table 1*. The figure also shows the photograph of a printed PTMA fabricated on a FR-4 substrate.

#### **MEASUREMENT RESULTS**

The HFSS-simulated current distributions of the printed PTMA at 3, 5, 7 and 9 GHz are shown in *Figure 3*. The simulation shows that the currents of the PTMA are almost distributed along the same directions (z-axis), which is similar to the behavior of a monopole

#### **TABLE I ANTENNA DIMENSIONS** $W_{mono}$ (mm) 17 $L_{mono}$ (mm) 7.6 $L_0 \, (mm)$ 1 90° $L_s(mm)$ 60 $W_s$ (mm 20 $L_{\sigma}$ (mm) 50 T (mm) (4.7, 0.018)PCB substrate ( $\varepsilon_r$ , tan $\delta$ )

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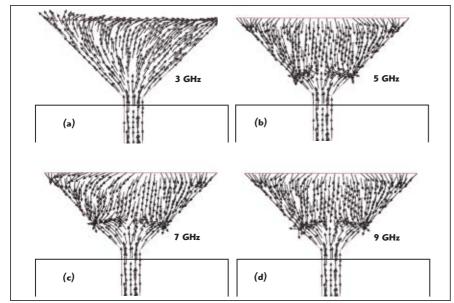
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▲ Fig. 3 HFSS-simulated current distribution of the printed PTMA at (a) 3, (b) 5, (c) 7 and (d) 9 GHz.

antenna. *Figure 4* shows the measured antenna input VSWR and the phase of the input impedance from 3 to 10 GHz. The measured input VSWR is less than 2.5 from 4 to 10 GHz and the measured phase distribution of the in-

put impedance is also quite linear except in the frequency range from 5 to 6 GHz. The measured representative H-plane (xy-plane,  $\theta = 90^{\circ}$ ) and E-plane (xz-plane,  $\Phi = 0^{\circ}$ ) antenna patterns at 4, 5, 6 and 7 GHz are shown in **Figure** 

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**5**. It can be seen that the H-plane patterns are all quite omni-directional.

#### RADIATED POWER SPECTRUM DENSITY (PSD)

For the conventional narrow-band antenna design, the frequency-domain information is more useful and significant than the one in the time domain. For a UWB radio system excited with a short pulse, the study of temporal properties will be helpful in designing and analyzing the UWB antenna. The desired time-domain information can be readily obtained by using time-domain numerical methods, such as the finite-difference time-domain (FDTD) method. However, since the FDTD method is inherently a near-field technique, a time-domain near- to far-field transformation is employed to efficiently compute the far-field antenna parameters.<sup>7,8</sup> Ultimately, the frequencydomain response can be obtained with the fast Fourier transform (FFT). The effect of various source pulses on the radiated PSD shaping are then studied by using the first-order Rayleigh pulses, which are differentiated Gaussian pulses. The parameter  $\sigma$  is used to describe the time duration when the normalized single level,  $v_0(\sigma)$ , of the source pulse equals to e<sup>-1</sup>. The first-order Rayleigh

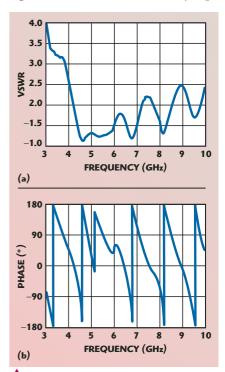


Fig. 4 Measured antenna input VSWR (a) and phase of the input impedance (b).

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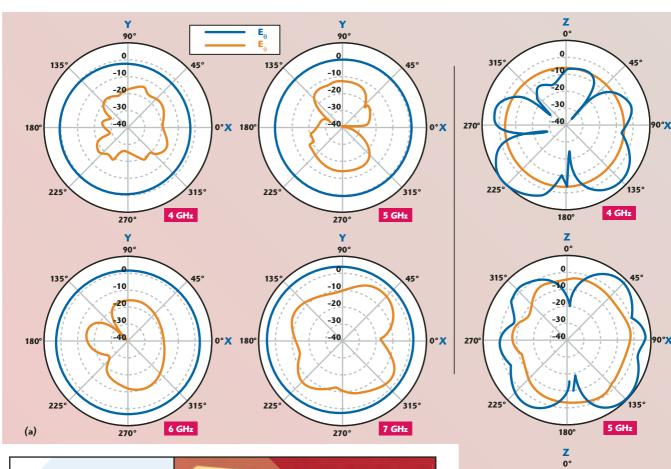


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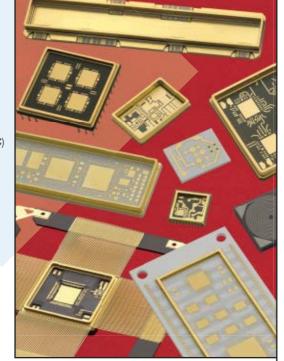
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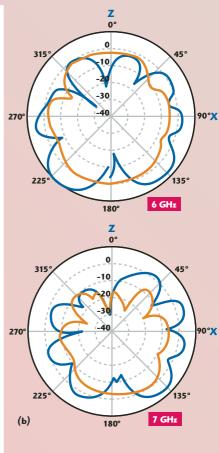
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▲ Fig. 5 Measured antenna patterns; (a) H-plane and (b) E-plane.



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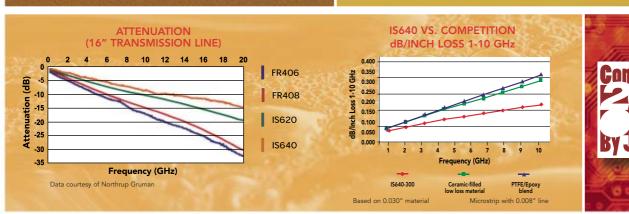
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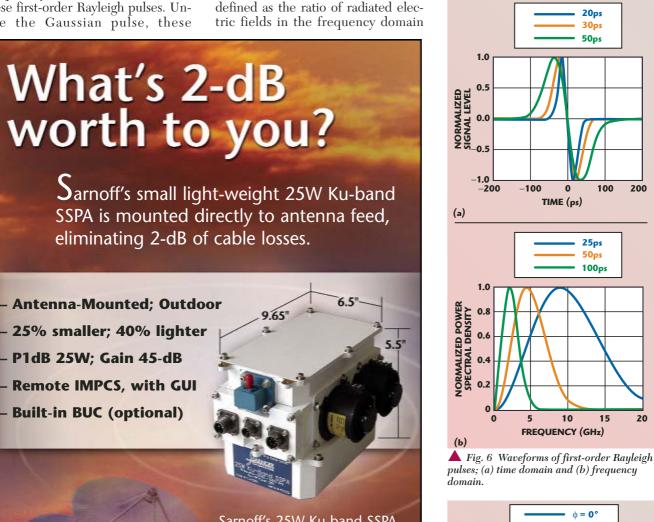


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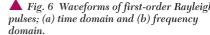
pulses with  $\sigma = 20$ , 30 and 50 ps are used in the FDTD computation. It is noted that the first-order Rayleigh pulses with  $\sigma > 60$  ps are not considered here because their corresponding spectra of 10 dB bandwidths do not fully occupy the desired 7.5 GHz bandwidth for UWB communication. Figure 6 shows the time-domain and frequency-domain waveforms of these first-order Rayleigh pulses. Unlike the Gaussian pulse, these

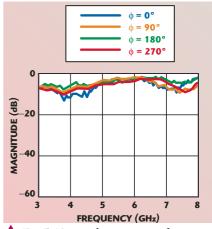
Rayleigh pulses are monocycle pulses in the time domain and do not generate any direct current (DC) component in the frequency domain. For UWB antenna design, the transfer function of the antenna is important both to comply with the FCC power emission limits and to preserve the transmitted waveform information. The transfer function of an antenna is

and the spectrum of a source signal (voltage) at the transmitting antenna.<sup>4</sup> For the FDTD calculation, the transfer functions of the antenna can be obtained by applying the definition. For measurement, the transfer functions can be derived from the transmission scattering parameters, S<sub>21</sub>, the input impedance and the an-



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🛕 Fig. 7 Measured antenna transfer function at  $\phi = 0^{\circ}$ , 90°, 180° and 270° in the H-



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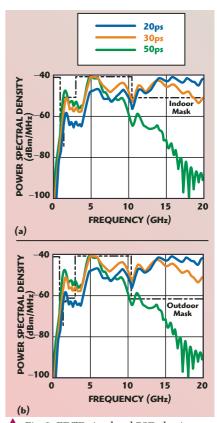
tenna gain.<sup>9</sup> The measured transfer functions of the printed PTMA at  $\Phi$  = 0°, 90°, 180° and 270° in the H-plane are plotted in **Figure 7**. Due to the instrument's limitations in the anechoic chamber, only the frequency band from 3 to 8 GHz is presented. A good agreement among transfer functions at  $\Phi$  = 0°, 90°, 180° and 270° is observed because of the omni-directional radiation pattern of the printed PTMA in the H-plane.

The magnitudes of the transfer functions are close to a flat response over the interested frequency band. From the signal point of view, this PTMA antenna is a bandpass filter with nearly constant magnitude. Hence, the desired radiated PSD of the printed PTMA can be achieved readily once the source pulses have been properly evaluated. *Figure 8* shows the computed radiated PSD of the printed PTMA excited by the first-order

Rayleigh pulses with  $\sigma = 20$ , 30 and 50 ps. The co-polarized component of the printed PTMA,  $E_{\theta}$ , in the direction of  $\theta = 90^{\circ}$  is computed at the distance of r = 2 m. All the computed results of PSD are normalized to -41.3 dBm/MHz. In comparison with the FCC's indoor and outdoor masks, it is found that the radiated PSD of the first-order Rayleigh pulses with  $\sigma$ = 20, 30 and 50 ps all comply with the FCC's indoor and outdoor mask from 2 to 10.6 GHz. Beyond 10.6 GHz, however, only the pulse with  $\sigma = 50$ ps can comply with the FCC's indoor and outdoor masks.

#### **CONCLUSION**

This article presents a PTMA for UWB communication. The HFSS 3-D EM simulator is employed for design simulation. The printed PTMA is fabricated on a FR-4 PCB substrate. The measured VSWR is less than 3 from 4 to 10 GHz. The measured phase distribution of the input impedance is quite linear (except in the frequency range from 5 to 6 GHz). The H-plane patterns are almost omni-directional in the UWB fre-



▲ Fig. 8 FDTD simulated PSD shaping of the E-field of the printed PTMA with first-order Rayleigh source pulses ( $\sigma$ =20, 30 and 50 ps); (a) indoor and (b) outdoor.







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quency band. The antenna transfer functions at  $\Phi=0^\circ, 90^\circ, 180^\circ$  and 270° in the H-plane are measured and a nearly flat response can be observed. The KSIR is used in the developed FDTD code to compute the time-domain far-field distribution. This is to investigate the PSD shaping to comply with the FCC emission limit mask. The effect of different source pulses (first-order Rayleigh pulses with  $\sigma=25, 50$  and 100 ps) on

the radiated PSD shaping is studied. Due to the flat response of the antenna transfer function, the desired radiated PSD of the printed PTMA can be readily achieved with a proper source pulse. It is found that only the radiated PSD of the first-order Rayleigh pulse with  $\sigma=50$  ps can comply with the FCC's indoor mask above 2 GHz. As for the outdoor mask, the same pulse can comply with the FCC emission limit.



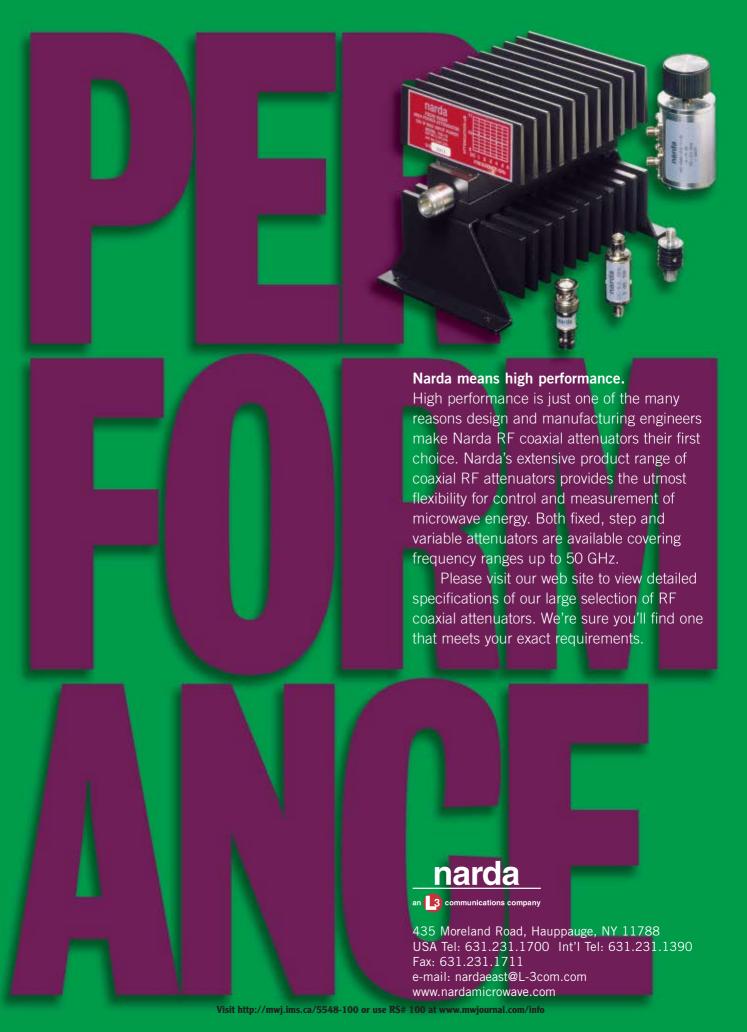
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# A NOVEL BROADBAND DESIGN OF A PRINTED RECTANGULAR SLOT ANTENNA FOR WIRELESS APPLICATIONS

A novel compact rectangular slot antenna printed on a dielectric substrate and fed by a 50  $\Omega$  microstrip is presented. Both impedance and radiation characteristics of this antenna are studied. Experimental results indicate that a 2:1 VSWR bandwidth of 3.95 GHz is achieved at operating frequencies from approximately 1.83 to 5.78 GHz, which is approximately five times that of a convectional printed wide-slot antenna. The good radiation characteristics of the constructed prototype antenna are also shown in this article. The broadband bandwidth and good radiation properties of the proposed design are suitable for most wireless applications.

The conventional printed wide-slot antenna has an operating bandwidth on the order of 10 to 20 percent. 1,2 Because modern wireless applications often require broadband operation, some printed wide-slot antennas for broadband operation have been reported.<sup>3-6</sup> A square slot antenna,<sup>3</sup> with a fork-shaped microstrip feed structure, was investigated for broadband operation. The fork-shaped microstrip feed structure was applied to a printed round corner rectangular wide-slot antenna<sup>4</sup> and a broadband design was achieved. A semicircular slot antenna<sup>5</sup> with a protruded small rectangular slot was excited by a 50  $\Omega$  microstrip. Recently, an isosceles triangular slot antenna<sup>6</sup> with a small rectangular slot for broadband operation was

proposed, and has shown an impedance bandwidth of 77 percent for a 2:1 VSWR. However, the impedance bandwidth of this antenna design is still not enough to cover most wireless applications. It is important to enhance the impedance bandwidth of microstrip-fed wideslot antennas.

In this article, a novel design of a microstrip-fed, printed rectangular slot antenna, with a small trapezoidal slot tuning for wireless applications, is proposed. The radiation characteristics of such a design are also

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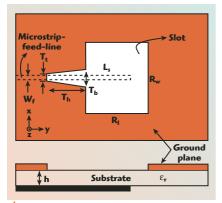


Fig. 1 The geometry of the proposed antenna.

investigated. The proposed antenna can be easily excited by a 50  $\Omega$  microstrip printed on an FR-4 dielectric substrate, and good impedance matching can be obtained for operation at frequencies within the wireless communications system bands. A comparison of the proposed design with a corresponding isosceles triangular slot antenna<sup>6</sup> is also given.

#### **ANTENNA DESIGN**

Figure 1 shows the geometry of the novel broadband rectangular slot antenna printed on a dielectric substrate. In this study, the dielectric substrate material is FR-4 with a thickness h = 1.6 mm and relative permittivity  $\epsilon_r$ = 4.4. For design convenience, the proposed antenna is fed by a 50  $\Omega$  microstrip, printed on the dielectric substrate. The microstrip, with a width  $W_f$ = 3.0 mm, is placed on the centerline of the rectangular slot (y axis). In order to achieve

broadband operation, a small trapezoidal slot is placed on the feed side of the rectangular slot. The primary slot is the rectangular slot, which has a horizontal width of R<sub>w</sub> and a vertical length of R<sub>I</sub>. The small trapezoidal slot has a top width Tt, a bottom width  $T_b$  and a vertical height  $T_h$ . The two slots are etched in the ground plane that is on the opposite side of the dielectric substrate. The design parameters of the proposed antenna can easily be determined. The perimeter of the polygonal slot at the lowest operating frequency required is given by

$$\begin{split} L_{\text{perimeter}} &= T_{\text{t}} + 2 \sqrt{T_{\text{h}}^2 + \left(\frac{T_{\text{b}} - T_{\text{t}}}{2}\right)^2} \\ &+ 2R_{\text{l}} + 2R_{\text{w}} - T_{\text{b}} \end{split} \tag{1}$$

The perimeter of the polygonal slot can be determined to be approximately two guided wavelengths in the slotline at the lowest operating frequency. Then, by fine tuning the small trapezoidal slot and adjusting the length of the 50  $\Omega$  microstrip feed-line, a new resonant mode can be excited in the proximity of the fundamental resonant mode and good impedance matching over a broad frequency range can be obtained.

#### EXPERIMENTAL RESULTS AND DISCUSSION

The proposed antennas were simulated with the High Frequency Structure Simulator (HFSS) from Ansoft and the prototypes were fabricated and

measured with a HP-8720ES network analyzer. The first parameter under design was the size of the rectangular slot. For the designs shown in Table 1, the ratio of R<sub>1</sub> to R<sub>w</sub> is approximately 1:1.5. To achieve the requirements wireless applications, the perimeter of the polygonal slot, L<sub>perimeter</sub>, was chosen to be approximately 180 mm, which corresponds to approximately  $2\lambda_{\sigma}$ at 1.83 GHz ( $\lambda_g$  is

frequency of operation). Table 2 shows L<sub>perimeter</sub> and bandwidth of all the antennas studied. Figure 2 shows the measured and simulated return loss results of the proposed antenna 1 with an impedance bandwidth of 104 percent for VSWR = 2. The impedance bandwidth obtained with the present design is approximately five times that of a conventional printed wide-slot antenna. From Tables 1 and 2, for antenna 1 with the widest bandwidth, the ratio of T<sub>b</sub> to R<sub>w</sub> is about 1:4 and the ratio of T<sub>t</sub> to T<sub>b</sub> is about 1:8. The optimal microstrip feed-line length L<sub>s</sub> was chosen to achieve a good impedance match for the constructed prototype. By observing the influence of various parameters on the antenna performance, it was found that the dominant factor in the proposed antenna designs for wireless communications applications is the perimeter of the polygonal slot in terms of  $\lambda_g$ . From that numerical experiment,  $\lambda_{\sigma}$  can be calculated as

$$\lambda_{g} = \frac{\lambda_{0}}{\sqrt{\varepsilon_{r,eff}}}$$
 (2)

where the  $\epsilon_{\text{r,eff}}$  is determined by

$$\epsilon_{r,eff} = \frac{\epsilon_r + 1}{2} \eqno(3)$$
 Then, the lowest frequency (f\_L) rela-

Then, the lowest frequency  $(f_L)$  relative to a half of the  $L_{perimeter}$  is formulated by

$$f_{\rm L} \approx \frac{C_0}{\frac{L_{\rm perimeter}}{2}} \left(\frac{1}{\epsilon_{\rm r,eff}}\right)^{\frac{1}{2}}$$
 (4)

where  $C_0$  is the speed of light in free space.

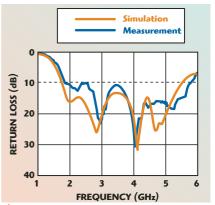


Fig. 2 Measured and simulated loss of antenna 1

#### **TABLE I DIMENSIONS OF THE PROPOSED ANTENNAS** $T_t$ $T_b$ 1.40 11.0 19.5 30 45 46 Antenna 1 7.0 30 46 4.60 19.5 45 Antenna 2 Antenna 3 4.60 11.0 23.7 30 45 46 (dimensions in mm)

#### **TABLE II CHARACTERISTICS OF THE PROPOSED ANTENNAS** $f_{l}$ (calculated) f<sub>L</sub> (GHz) f<sub>H</sub> (GHz) BW (%) Antenna 1 180.4 2.02 1.83 5.78 104 Antenna 2 186.6 1.96 1.95 4.08 71 Antenna 3 191.2 1.91 2.13 6.00 95



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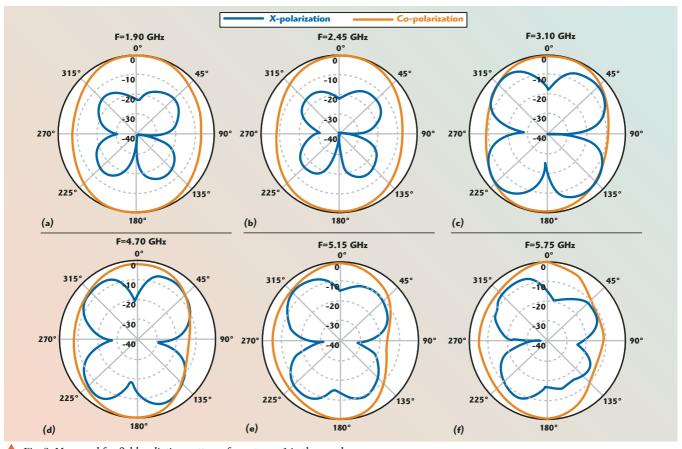




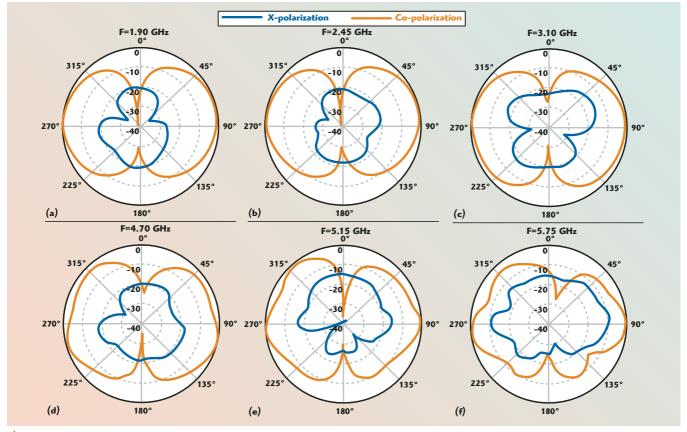


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▲ Fig. 3 Measured far-field radiation patterns for antenna 1 in the x-z plane.



▲ Fig. 4 Measured far-field radiation patterns for antenna 1 in the y-z plane.

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Gali — S66	DC-3000	22	2.8	2.7	18	136	16	3.5	.99
Gali — 3	DC-3000	22.4	12.5	3.5	25	127	35	3.3	.99
Gali — 6F	DC-4000	12.1	15.8	4.5	35.5	93	50	4.8	1.29
Gali — 4F	DC-4000	14.3	15.3	4.0	32	93	50	4.4	1.29
Gali □ 51F	DC-4000	18.0	15.9	3.5	32	78	50	4.4	1.29
Gali □ 5F	DC-4000	20.4	15.7	3.5	31.5	103	50	4.3	1.29
Gali □ 55	DC-4000	21.9	15.0	3.3	28.5	100	50	4.3	1.29
Gali □ 52	DC-2000	22.9	15.5	2.7	32	85	50	4.4	1.29
Gali	DC-4000	12.2	18.2	4.5	35.5	93	70	5.0	1.49
	DC-4000	14.4	17.5	4.0	34	93	65	4.6	1.49
	DC-4000	18.1	18.0	3.5	35	78	65	4.5	1.49
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	DC-1000	25.1	18.3	2.7	38	120	80	4.8	2.35

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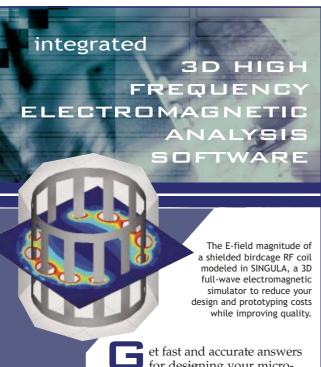
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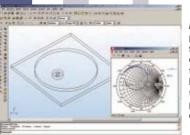
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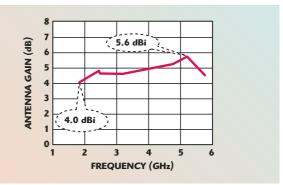
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📤 Fig. 5 Measured peak gain of antenna 1.

#### TABLE III **CHARACTERISTICS OF THE PROPOSED ANTENNA** AND THE ISOSCELES TRIANGLE ANTENNA

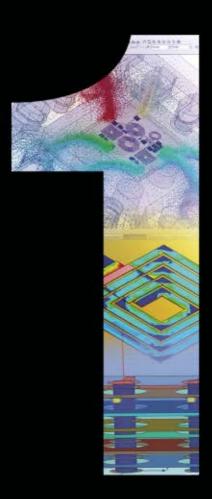
	Maximum Antenna Gain (dB)	Gain Variation (dB)	f <sub>L</sub> (GHz)	f <sub>H</sub> (GHz)	BW (%)
The isosceles triangular slot antenna <sup>6</sup>	5.9	1.8	2.33	5.23	77
The proposed antenna (Antenna 1)	5.6	1.6	1.83	5.78	104

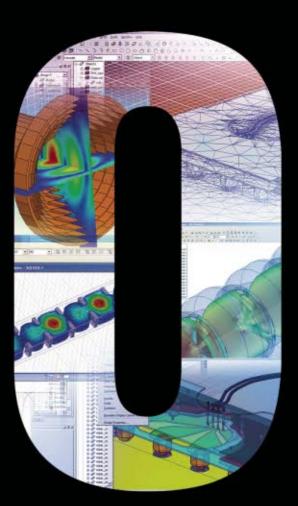
For the reasons mentioned above, antenna 1 is the optimum design. Its radiation characteristics have been measured in the STUT Anechoic Chamber. Figures 3 and 4 show the measured radiation patterns in the x-z plane and y-z planes, respectively, at F = 1.90, 2.45, 3.10, 4.70, 5.15 and 5.75 GHz. Antenna 1 is suitable for GSM (1900 to 1990 MHz), PCS (1900 to 1990 MHz), IMT-2000 (1920 to 2170 MHz), Bluetooth (2400 to 2484 MHz), IEEE 802.16a/e, IEEE 802.11b/g (2400 to 2484 MHz), IEEE 802.15.3a (UWB), PHS (1905 to 1915 MHz), PACS (1930 to 1990 MHz), UMTS (Regular 1, 2, 3), IEEE 802.11a (5150 MHz) and HIPERLAN /1 /2 (5150 MHz). It is also noted that, for antenna 1, the radiation patterns in the x-z plane and y-z plane are good, which makes the proposed antenna suitable for practical applications. The measured peak antenna gain for antenna 1 is also presented in *Figure 5*. It shows a peak gain of approximately 5.6 dBi; the gain variation is observed to be less than 1.6 dB.

A comparison of the proposed design with a corresponding isosceles triangular slot antenna<sup>6</sup> is given in **Table 3.** It shows a small gain variation for the proposed antenna design compared to that of the isosceles triangular slot antenna. In addition, the 104 percent impedance bandwidth of the proposed antenna is larger than that of the isosceles triangular slot antenna.

#### CONCLUSION

A microstrip-fed, printed rectangular slot antenna with a small trapezoidal slot for broadband operation has been implemented. Experimental results show that the impedance bandwidth of a printed rectangular slot antenna can be significantly improved by selecting the proper dimen-





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#### **ACKNOWLEDGMENT**

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# A DESIGN OF DOUBLE T-TYPE MICROSTRIP ANTENNAS FOR BROADBAND AND CONTROL OF RESONANCE

In this article, the design and fabrication of a planar, wide band, microstrip antenna is proposed where the resonance frequency is controlled. This new configuration for a wide band microstrip antenna shows an omni-directional radiation pattern. By properly choosing the gap between the stubs and the length of the upper stub, the resonance frequency can be controlled over approximately 700 MHz. An antenna impedance bandwidth of 450 MHz (VSWR = 2.0) can be obtained within the IMT2000 frequency band. The characteristics of the proposed antenna were analyzed using the FDTD method.

atch antennas, printed on a circuit board, are suitable for integration within a communication device since they occupy a very small volume within the system, while at the same time decreasing the final product fabrication cost. The use of this kind of printed patch antenna permits concealing the antenna within the system, so that possible damage caused by a protruding antenna can be avoided. A number of researchers have studied the improvements relating to the narrow bandwidth of patch antennas. In this article, a solution to the problems of narrow bandwidth and frequency control is offered. A bandwidth of 22.5 percent was required for this antenna. It was difficult to find the required resonance frequency relative to the electrical size of the antenna. Antennas have been designed with a very small size relative to the wavelength at the operating frequency. A modified planar T-type microstrip antenna is proposed as a viable solution, where the resonance frequency is controlled by adjusting the length of the stub. The proposed dual-T antenna uses two stubs, which are fed by a CPW transmission line. Experimental results show that the frequency tuning depends on the lengths and gap of the dual stubs. The frequency shift is determined mainly by calculating the gap between stubs and the length of the upper stub. Several designs were investigated experimentally and, within these, the characteristics of the input impedance and radiation patterns were analyzed. This article

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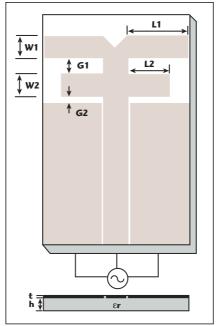




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▲ Fig. 1 Geometry of the proposed dual-T antenna.

# TABLE I DESIGN PARAMETERS FOR THE PROPOSED ANTENNA L1 (mm) 14 G1 (mm) 4 L2 (mm) 10 G2 (mm) 1.5 W1 (mm) 6 W2 (mm) 6

details the design of the IMT2000 band antenna and the construction and analysis of its prototypes. The impedance bandwidth obtained was ap-

proximately 470 MHz, as determined from a return loss of –10 dB.

#### ANTENNA DESIGN AND DESCRIPTION

The design of CPW-fed patch antennas has received a lot of attention recently. This is because a CPW-fed patch antenna has the advantage of offering a significant bandwidth, while being easy to integrate within monolithic microwave integrated circuits (MMIC) and low temperature co-fired ceramic circuits (LTCC). A few attempts have been made to increase the bandwidth of CPW-fed patch antennas. The geometry of the proposed CPWfed dual-T microstrip patch antenna is shown in Figure 1. Table 1 shows the parameters used in the design of the antenna. The antenna was printed on an FR4 substrate with a thickness h = 1.6 mm and a relative permittivity  $\varepsilon_r =$ 4.2, with a length of  $\sqrt{14}$  to  $\sqrt{13}$  and a width of 6 mm. The antenna was excited by a CPW feed line, whose impedance is controlled by the width of the strip and the gap between the strip and ground. The gap between the two stubs was set at G1 = 4 mm. The spacing between the lower stub and the edge of the ground plane was G2 = 1.5 mm. The length of the upper and lower stubs were chosen as L1 = 14 mm and L2 = 10 mm, respectively. The dual-T microstrip patch antenna was fabricated and analyzed with various design parameters. As a first step, the input im-

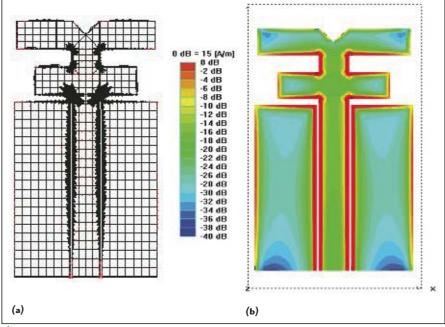
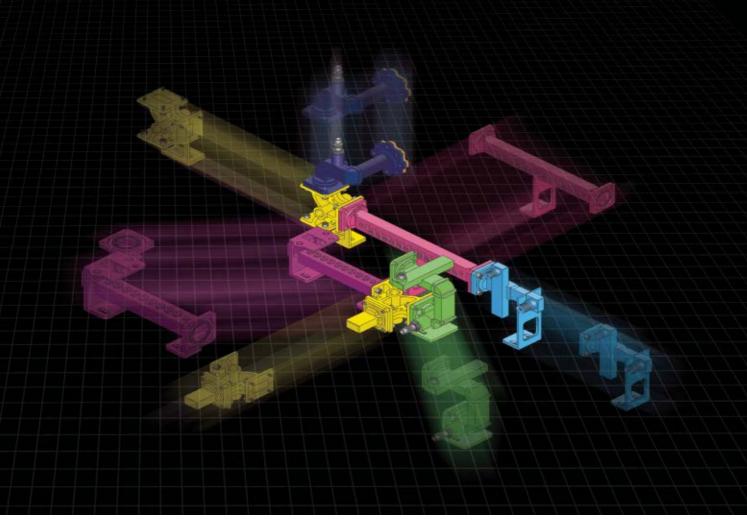


Fig. 2 Simulated vector surface current (a) and electrical field distribution (b) at 1.8 GHz.



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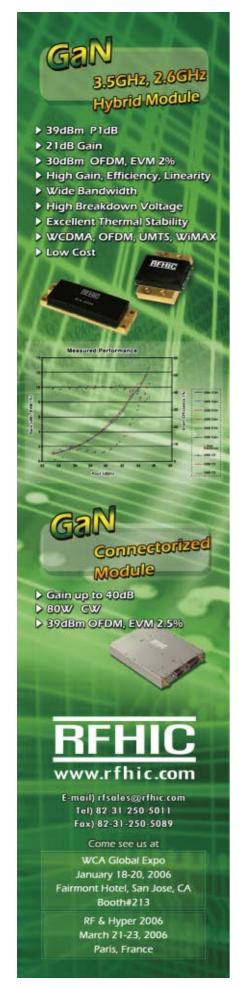
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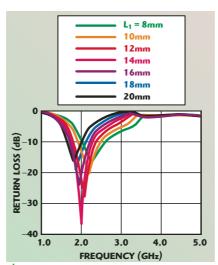


Fig. 3 Simulated return loss versus frequency for different L1 stub lengths.

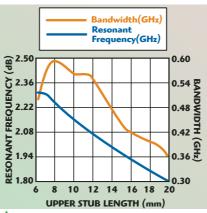
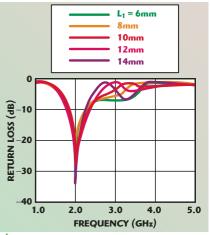


Fig. 4 Resonant frequency and bandwidth versus upper stub length.

pedance was obtained as a function of the width and gap of the CPW-feed line. The L1, L2, G1 and G2 parameters were then varied and their effect on the characteristics of the antennas was investigated. Figure 2 shows the simulated surface current distribution at 1.8 GHz. The current distribution at the edge of the dual stub is zero. Figure 3 shows the simulated return loss versus frequency for different lengths of the upper stub L1. The value of L1 was varied from 8 to 20 mm. When L1 was increased from 8 to 20 mm, the fundamental resonance was shifted to a lower frequency. However, when L1 increased beyond 20 mm, there was a poor response in the fundamental resonance. A large frequency shift occurred in the fundamental resonance when changing the parameter L1. The values for L2, G1 and G2 were fixed at 10, 6 and 1.5 mm, respectively. Figure 4 shows the resonating frequency and bandwidth versus the length of the up-



▲ Fig. 5 Simulated return loss versus frequency for different lengths of the lower stub. I.z.

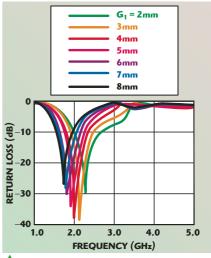


Fig. 6 Simulated return loss versus frequency for different gaps, G1.

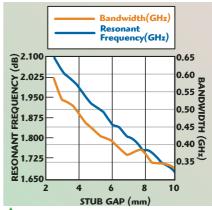


Fig. 7 Resonance frequency and bandwidth versus gap between stubs, G1.

per stub. It shows that the fundamental resonant frequency varies inversely with the length L1. *Figure 5* shows the simulated return loss versus frequency as a function of the length of the lower stub of the dual-T antenna L2, varying

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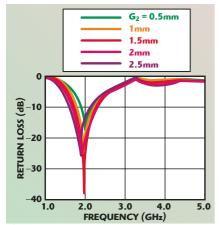
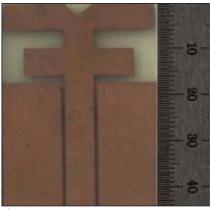


Fig. 8 Simulated return loss versus frequency for various gaps, G2.

from 6 to 14 mm. When L2 is increased from 6 to 14 mm, the fundamental resonant frequency does not shift, but the return loss changes. *Figure 6* shows the return loss when G1 is varied from 2 to 8 mm. The center frequency of the antenna changed appreciably. When G1 was increased from 2 to 8 mm, the fundamental resonance shifted to a low frequency. Here, the values of L1, L2 and G2 were fixed at



▲ Fig. 9 The fabricated antenna.

14, 10 and 1.5 mm, respectively. Figure 7 shows the resonance frequency and bandwidth versus the gap between the dual stubs. The resonance frequency varies inversely with the length of the gap G1. Figure 8 shows the return loss simulated for a change in the gap G2 between 0.5 and 2.5 mm while keeping L1 = 14 mm, L2 = 10 mm and G1 = 4 mm. The resonance frequency does not show much change. Figure 9 shows a photograph of the fabricated antenna. Figure 10 shows a compari-

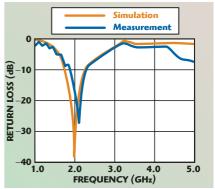
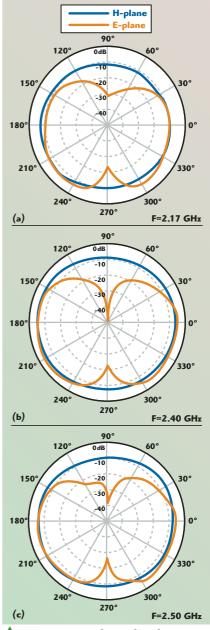


Fig. 10 Measured and simulated return loss versus frequency.



▲ Fig. 11 Measured E- and H-plane radiation patterns at (a) 2.17, (b) 2.40 and (c) 2.50 GHz.





son between the measured and simulated return losses of the antenna. The simulated and measured data of the proposed antenna are approximately the same. Some errors occurred due to phase differences between the two stubs as a result of poor manufacturing in the laboratory. *Figure 11* shows typical measured omni-directional radiation patterns of the antenna at three frequencies, plotted along the E-plane (y-z plane) and H-plane (x-z plane).

#### **CONCLUSION**

CPW-fed dual-T antennas, with a widened tuning stub for broadband operation and controlled frequency, were designed and successfully fabricated. The efficient proposed antenna was achieved simply by tuning the gap between the stubs and the length of the upper stub. The return loss and radiation patterns were simulated by using the FDTD method and were measured using a vector net-

work analyzer, model 37325A, and an anechoic chamber Stargate-32A. By properly choosing the gap between stubs and the length of the upper stub, the center frequency can be shifted by approximately 700 MHz. An antenna impedance bandwidth of 450 MHz can be obtained within the IMT2000 band.

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  7. H.M. Chen and Y.F. Lin, "Printed Monopole Antenna for 2.4/5.2 GHz Dual-band Operation," *IEEE International Symposium on Antennas and Propagation Digest*, Vol. 3, June 2003, pp. 60–62.

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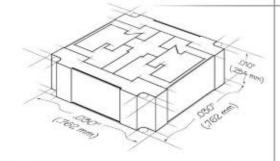


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# EXPERIMENTAL ANALYSIS OF A MULTI-BAND AND HIGH GAIN OPEN SLOT ANTENNA WITH DUAL REFLECTOR

In this article, a wide-band, open slot antenna with dual reflectors is proposed. It has been constructed and its performance measured. It has a modified circular feed structure for easy impedance matching to the wide slot. The dual reflectors lead to a reduced beam-tilt angle and an improved half-power beam width in the E-plane for each frequency band. Bandwidths of 24.7 percent (755 to 968 MHz) and 73.1 percent (1574 to 3389 MHz) were obtained for a VSWR less than 2.0. This antenna also offers high gain characteristics. The proposed antenna can be used in cellular, GSM, DCS, PCS, IMT-2000 and WLL applications.

lot antennas have been investigated since at least the 1940s¹ and are treated in many textbooks on electromagnetism. In these antennas, the feeding method generally uses a microstrip line crossing the center of the slot. However, this method increases the radiation resistance, which makes the impedance matching difficult.² To solve this problem, Yoshimura³ and Pozar⁴ have proposed a second way, which offsets a short-circuited tuning stub and an open circuit-tuning stub at both ends of the slot.

Bi-directional slot antennas for broadband operation (30 to 90 percent) have been described. <sup>5,6</sup> Unfortunately, these antennas have a low gain. A directional slot, backed by a ground plane, has shown higher gain than a bi-directional slot antenna, but the radiation pattern of a directional antenna has many nulls at higher frequencies, which restrict a wider application for wireless communications. Therefore, a technique to enhance the

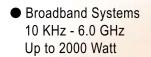
radiation of microstrip antennas has been proposed,<sup>7</sup> although the narrow bandwidth of the antenna is still a major obstacle. An open slot structure has already been published;<sup>8</sup> however, its major fault is a beam tilt and a narrow half-beam width at cellular, DCS, PCS, IMT-2000 and WLL frequencies.

In this article, a new structure for a printed, open slot antenna with dual reflectors is proposed. An open slot antenna is made by etching a rectangular slot in the ground plane of a microstrip. The proposed antenna uses a modified circular feed structure, which can provide a good impedance match for a wide

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slot. Moreover, the dual reflectors (reflectors 1 and 2) lead to an enhanced beam tilt angle and half-power beam width of the E-plane pattern in each frequency band. This antenna also shows wide-band and high gain characteristics.

#### ANTENNA STRUCTURE AND EXPERIMENTAL RESULTS

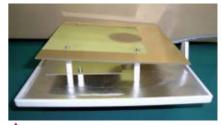
The geometry of the proposed circular-fed, open slot antenna with dual reflectors for dual- and wide-band operation is shown in *Figure 1*. The open slot antenna is etched in the

ground plane on the substrate FR-4 ( $\epsilon_r = 4.3$ ) with a thickness  $t_1 = 1.6$  mm. The open slot antenna has a slot width  $w_s$  and a length  $l_s$ , chosen to improve bandwidth, and the top of the slot is opened to reduce the radiation tilt angle in the E-plane for practical applications. The microstrip line width  $w_1$  is designed for a 50  $\Omega$  input impedance. The modified circular microstrip feed line is used as a feeding method to match easily to the wide slot. The reflectors 1 and 2 are positioned with height  $h_1$  and  $h_2$  from the back of the open slot antenna. Reflec-

tor 1 is used for the upper band impedance matching and directional pattern; Reflector 2 is used for enhancing the beam tilt angle and providing an increment in the halfpower beam width in the E-plane pattern. Figure 2 shows a photo of the fabricated antenna. The reflectors are made of aluminum plates and the antenna is fed through a coaxial cable and a  $50 \Omega$  SMA connector. The fabricated antenna dimensions are  $l_c = 120$  mm,  $w_c$  $= 132 \text{ mm}, \text{ w}_{c} = 32$ mm,  $w_d = 2.5$  mm,  $h_1 = 28 \text{ mm} \text{ and } h_2 =$ 45 mm. The low frequency band is affected by l<sub>s</sub>, w<sub>s</sub> and h<sub>2</sub>. The upper band is affected by w<sub>c</sub>, w<sub>d</sub> and  $h_1$ . The overall size of the proposed antenna is 180 mm  $\times$  160 mm  $\times$  47.6 mm. The VSWR of the proposed antenna was measured with an HP8753 ES network analyzer. The far-field radiation patterns were measured in an anechoic chamber.

The measured VSWR data of the proposed antenna is

shown in *Figure 3*. The measured bandwidth is 755 to 968 MHz in the



📤 Fig. 2 The fabricated antenna.

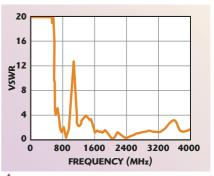


Fig. 3 Measured VSWR versus frequency.

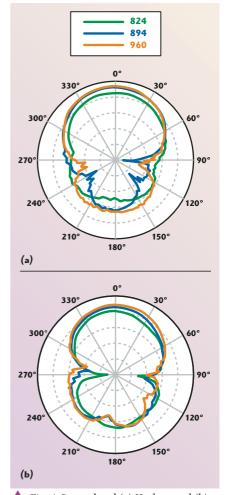
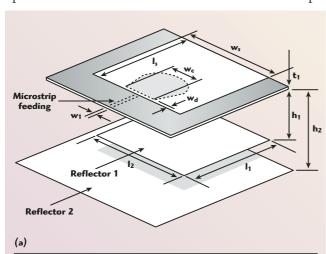
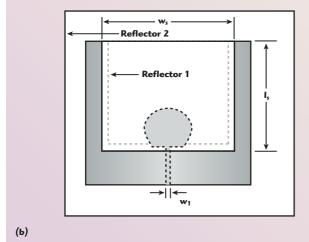
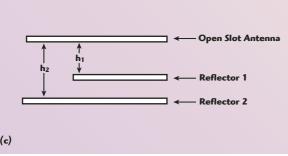


Fig. 4 Lower band (a) H-plane and (b) E-plane radiation patterns.







▲ Fig. 1 Structure and design parameters of the proposed antenna; (a) three-dimensional view, (b) top view and (c) side view.



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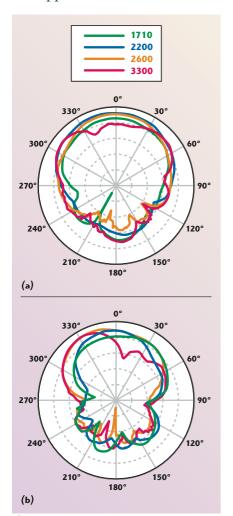


Fig. 5 Upper band (a) H-plane and (b) E-plane radiation patterns.

bandwidth is approximately 24.7 percent at the lower band and 73.1 percent at the upper band. The proposed antenna shows its dual-band and wide-band characteristics. After calibration, the far-field radiation patterns were measured using a horn antenna. Figure 4 shows the H-plane and E-plane radiation patterns at the lower band. Figure 5 shows the Hplane and E-plane radiation patterns at the upper band. **Table 1** shows the measured characteristics (gain, beam tilt angle and half-power beam width (HPBW) of the E-plane) of the proposed antenna. This antenna reduces

the beam tilt angle of the E-plane for practical applications such as DCS, PCS, IMT-2000 and DMB. The measured maximum gain is 9.51 dBi at 0.96 GHz and 8.46 dBi at 2.2 GHz, respectively.

The measured gain versus frequency for the cellular and GSM bands is shown in *Figure 6*. The gain is relatively high over most of the band, which is most probably due to the effect of the finite size of the antenna substrate, that is the power in the surface wave is not confined to the substrate but diffracted by the substrate edge, an effect which was

TABLE I							
	MEASURED CH	ARACTERISTICS					
Frequency (MHz)	Gain (max) (dB)	E-plane Beam Peak Angle (°)	E-plane HPBW (°)				
Lower Band							
824	5.5	-2	69.94				
894 960	8.78 9.51	0	66.18 62.26				
Upper Band							
1710 1880 2000	5.6 5.55 7.87	-2 0 10	62.65 84.52 84.4				
2100 2200	8.42 8.76	-2 -6	67.6 75.73				
2300 2600 3000 3300	8.1 7.55 7.8 4.3	-4 -2 -2 -48	58.38 55.34 32.74 28.93				

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AF01-4151510B AF01-4281512B AF01-4401512B	0.1 - 4	15 28 40	± 0.5 ± 0.6 ± 0.75	1.5 1.5 1.5	2:1	+ 10 + 12 + 12	+12	60 90 120
AF01-6132513B AF01-6252513B AF01-6362513B	0.1 – 6	13 25 36	± 0.5 ± 0,6 ± 0.8	2.5 2.5 2.5	2:1	+ 13 + 13 + 13	+12	60 90 120
AF01-8183013B AF01-8273013B AF01-8363013B	0.1 – 8	18 27 36	± 0.5 ± 0.75 ± 1.0	3.0 3.0 3.0	2:1	+ 13 + 13 + 13	+12	80 110 140
AF0110163013B AF0110243013B AF0110323013B	0.1 - 10	16 24 32	± 0.5 ± 0.75 ± 1.0	3.0 3.0 3.0	2:1	+ 13 + 13 + 13	+12	80 110 140
AF0112153013B AF0112223013B AF0112303013B	0.1 - 12	15 22 30	± 0.5 ± 0.75 ± 1.0	3.0 3.0 3.0	2:1	+ 13 + 13 + 13	+12	80 110 140
AF0116153013B AF0116223013B AF0116293013B	0.1 – 16	15 22 29	± 0.75 ± 1.0 ± 1.25	3.0 3.0 3.0	2:1	+ 13 + 13 + 13	+12	80 110 140
AF0118153515B AF0118223516B AF0118293516B	0.1 – 18	15 22 29	± 1.0 ± 1.25 ± 1.5	3.5 3.5 3.5	2:1	+ 15 + 16 + 16	+12	80 110 140
AF0120153511B AF0120233513B AF0120303513B	0.1 - 20	15 23 30	± 1.0 ± 1.5 ± 1.75	3.5 3.5 3.5	2:1	+ 11 + 13 + 13	+12	80 110 140
AF0118193A AF0118273A AF0118353A	0.1 - 18	19 27 35	± 0.8 ± 1.2 ± 1.5	2.8 2.8 3.0	2:1	+ 8 + 10 + 15	+5	60 100 150
AF0120183A AF0120253A AF0120323A	0.1 - 20	18 25 32	± 0.8 ± 1.2 ± 1.6	2.8 2.8 3.0	2:1	+ 8 + 10 + 10	+5	60 100 130
AF00118173A AF00118253A AF00118333A	0.01 - 18	17 25 33	± 1.0 ± 1.4 ± 1.8	3.0 3.0 3.0	2:1	+ 8 + 10 + 12	+5	60 100 150
AF00120173A AF00120243A AF00120313A	0.01 - 20	17 24 31	± 1.0 ± 1.5 ± 2.0	3.0 3.0 3.0	2:1	+ 8 + 8 + 8	+5	60 90 120

\*Noise figure higher @ frequencies below 500 MHz



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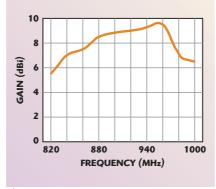
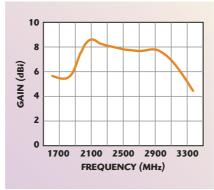


Fig. 6 Measured antenna gain in the lower frequency band (cellular and GSM).



▲ Fig. 7 Measured antenna gain in the upper frequency band (PCS, IMT-2000 and WLL-band).

not taken into account in the analysis. The measured gain is 5 dBi over the entire usable frequency band, but drops off rapidly past the band edges. The measured gain versus frequency for the PCS, IMT-2000 and WLL bands is shown in *Figure 7*. The measured gain is also 5 dBi over the entire band in the usable frequency band, but drops off rapidly past the band edges. This is due to impedance mismatch and pattern degradation, as the back radiation level increases rapidly at these frequencies.

### CONCLUSION

In this article, a modified, circularfed, open slot antenna with dual reflectors is proposed. The measured bandwidth of the proposed antenna is approximately 24.7 percent at the lower band and 73.1 percent at the upper band for a VSWR ≤ 2.0. The experimental results of this antenna showed a multi-band and a high gain characteristic. The proposed antenna offers a reduced beam tilt angle of the E-plane pattern for practical applications such as cellular, GSM, PCS, IMT-2000 and WLL. ■

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Hyun-Chul Go received his BS and MS degrees in electronics engineering from the Korea University of Technology and Education, Cheonan, Korea, in 1999 and 2001, respectively. Since 2001, he has been working as a research engineer in the R⊕D

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Yong-Woong Jang received his BS and MS degrees from Myongji University, Seoul, Korea, in 1989 and 1991, respectively, and his PhD degree from Ajou University, Suwon, Korea, in 1999, all in electronics engineering. He is currently an associate

professor in the department of information communications engineering at Keukdong College, Chungbuk, Korea. His main areas of interest include antennas, RF systems and numerical methods in solving electromagnetic

# FEATURED MODELS

Model #	Frequency		hase Noise :/Hz)
	(MHz)	@10 kHz	@100 kHz
FSW Series [Dual	supply voltage +5 &	+15 VDC]	
FSW511-50	50 to 115	-103	-120
FSW1125-50	110 to 250	-100	-122
FSW1536-50	150 to 360	-100	-120
FSW1847-50	180 to 470	-95	-120
FSW1847-100	180 to 470	-98	-120
FSW2462-50	230 to 620	-95	-119
FSW60160-50	600 to 1600	-90	-117
FSW150290-50	1500 to 2900	-85	-107
FSW190410-50	1900 to 4100	-82	-107
FSW Series [Dual	supply voltage +5 &	+24 VDC]	
FSW514-50	50 to 140	-103	-120
FSW1129-50	110 to 290	-100	-122
FSW1545-50	150 to 450	-100	-120
FSW1857-50	180 to 570	-95	-120
FSW1857-100	180 to 570	-98	-120
FSW2476-50	240 to 760	-95	-119
FSW60170-50	600 to 1700	-90	-117
FSW150320-50	1500 to 3200	-85	-107
FSH196225-50	1960 to 2250	-94	-119
LFSW Series [Sine	gle Supply voltage +5	VDC]	100
LFSW514-50	50 to 140	-102	-120
LFSW1129-50	110 to 290	-99	-122
LFSW1545-50	150 to 450	-98	-120
LFSW1857-50	180 to 570	-94	-120
LFSW1857-100	180 to 570	-98	-120
LFSW2476-50	240 to 760	-94	-119
LFSW35105-50	350 to 1050	-108	-130
LFSW60170-50	600 to 1700	-90	-117
LFSW150320-50	1500 to 3200	-85	-107
LFSW190410-50	1900 to 4100	-82	-107
LFSH196225-50	1960 to 2250	-93	-123

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esign engineers currently using CST MICROWAVE STUDIO® (CST MWS) appreciate its ease-of-use and the insight into devices which together facilitate a significant augmentation of throughput. Now though, these customers may be taken by surprise, because the box containing the eagerly awaited and much publicized new release is titled CST STUDIO SUITE™ 2006. Closer inspection reveals that this suite comprises the high frequency simulator CST MWS, the block schematic tool CST DE-SIGN STUDIOTM (CST DS), the low frequency simulator CST EM STUDIOTM (CST EMS), and last but not least, CST PARTICLE STUDIO<sup>TM</sup> (CST PS) dedicated to the fully consistent 3D simulation of free moving charged particles in electromagnetic fields. Figure 1 shows the CST STUDIO SUITETM 2006 interface.

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The synergetic advantages offered by this new suite should be all too apparent to users. For example, CST EMS' temperature solver can be used to evaluate the heat load due to high frequency electric field losses calculated by CST MWS, or the magnetization of ferrites, and all within one interface. An illustration is given in *Figure 2*.

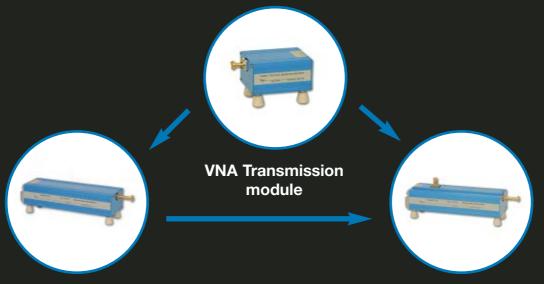
This is made possible by the newly implemented CST DESIGN ENVIRONMENT<sup>TM</sup> (CST DE), which is the access point to CST MWS and all other CST STUDIO simulators. Through the implementation of CST DE, CST MWS has gained a Multiple Document Interface, whereby several projects can be

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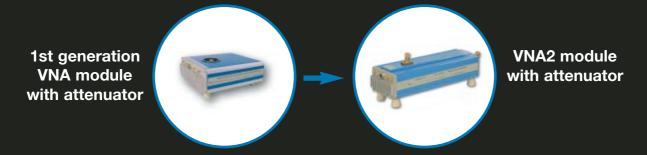
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opened simultaneously. Therefore, the user can easily switch between projects, compare and copy/paste results. CST DE also allows switching to the VBA editor.

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▲ Fig. 1 CST STUDIO SUITE<sup>™</sup> 2006 interface.

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### **MODELING AND INTEROPERABILITY**

The success of CST MWS has always been closely related to having introduced an easy-to-use interface to the

3D EM field simulation community. It allows fast modeling of complex structures, promoting design intent capture and implicit (together with explicit and even subsequent) parameterization of geometrical models. A wide range of interfaces to mechanical CAD tool formats is available too, and the imported CAD data can be parameterized and made accessible to optimization.

Entirely new are the interfaces to VDA-FS and Mecadtron formats. The interface to Cadence® Allegro® has undergone a complete rework, resulting in improved front-end performance. *Figure 3* shows a structure imported from Cadence. The interface also now features a stack-up editor. This represents a first step towards interfacing with other EDA-vendors like Mentor Graphics® or Zuken. Planar imports can be easily extended by an automated JEDEC compliant bondwire creation and users can simply switch between an idealized and a solid model representation. In addition to CAD inter-

faces, current distributions, from SimLab PCBMod, for example, can now be loaded as sources for EMC/EMI studies.

### **SCHEMATIC VIEW**

Upon opening a CST MWS project, the user will notice that an additional CST DS view is available. Even with the basic license, RLC elements as well as a few other components can be attached to the ports, and S-parameter simulations can be performed. A full CST DS license would enable access to a far wider range of circuit elements. The composition of larger systems out of small 3D CST MWS models (but also models originating from other simulation methods) is the key strength of

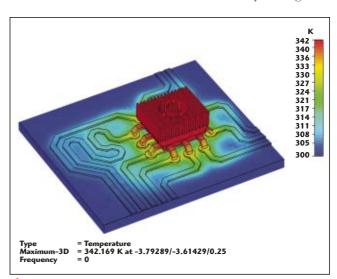


Fig. 2 Temperature distribution of an IC cooling element.

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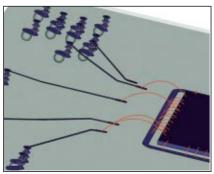
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CST DS. It employs sophisticated caching and interpolation schemes to speed up parameter studies and optimizations. It is strongly focused on improving 3D EM simulation performance, and takes some users one step along the path towards circuit simulation.

## **EM/CIRCUIT CO-SIMULATION**

A major concern in today's high frequency design of PCBs and packages is signal integrity and radiated emission. With Agilent's ADS 2005A and CST MWS 2006, the companies now present an improved EM/circuit co-simulation scheme that enables the complete integration of 3D models in the ADS workflow. Any CST MWS model can be made available for co-simulation as a library element.



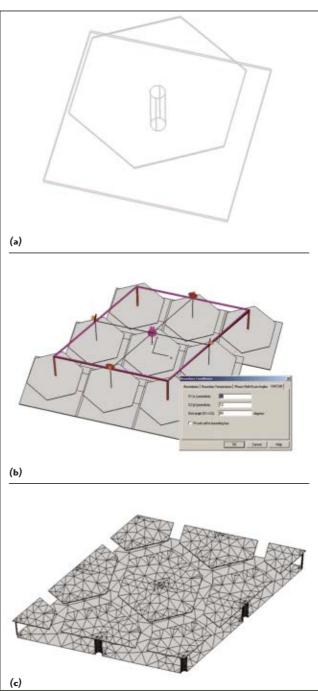
▲ Fig. 3 Structure imported from Cadence.

The user can specify the parameters to be made accessible in the ADS circuit model. If used in tuning or optimization, intermediate results can be obtained by interpolating existing results. Whenever necessary (or wanted) a full 3D simulation can be

launched directly from the ADS schematic. Each simulation result is added to the library element cache, thus continuously increasing its value.

# **SOLVER TECHNOLOGY**

CST MWS is said to be the only commercial 3D simulator to offer time domain and frequency domain on Cartesian and tetrahedral grids, accessible through one easy-to-use interface. The flagship module, the transient solver, is the first choice for electrically large, complex or broadband structures. These capabilities have been extended by the implementation of 64-bit technology. Be-



▲ Fig. 4 Creation of a unit cell; (a) single element, (b) automatic set-up of the unit cell and (c) the Floquet mode port boundary, calculation domain.



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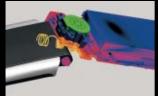
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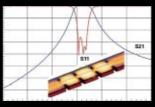
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sides the user interface, the company's proprietary Perfect Boundary Approximation (PBA\*) technique can be seen as the other foundation stone on which its success has been built. Its implementation has been shown to significantly improve the efficiency of time domain methods through accurate geometrical structure representation.

The transient solver now takes advantage of a new meshing algorithm. The robust mesher shows excellent performance particularly for complex, imported structures.

Further improvements include the definition of frequency dependent material through tables. This also applies to voxel imports, thus enabling highly accurate broadband EM simulation of biological tissues.

The main focus of development for version 2006 has been the tetrahedral frequency domain (FD) solver. This complements the time domain solver, and shows its particular strengths if structures are electrically small or periodic. Particularly interesting is the ability to mesh the true surface of the structure without having to pre-segment rounded objects. Users can choose between an iterative solver, where memory requirements scale better with problem size, and a direct solver, which performs efficiently on multi-port structures, since the simulation time is not strongly dependent on the number of ports.

For periodic structures like phased arrays, PBGs, FSS and meta-materials the FD solver features a powerful algorithm that automatically sets up the unit cell for easy scan angle study. This is illustrated in *Figure 4*. Also, an adaptive frequency sweep speeds up broadband investiga-



tions by reducing the number of simulations necessary to achieve the desired accuracy.

There are now two dedicated solvers for resonant high Q structures like filters. The first is based on a model order reduction (MOR) scheme, and calculates S-parameters directly and extremely quickly but without calculating fields. If the fields are required, the modal analysis approach can be applied. The Eigenmode solver that solves closed or periodic structures, taking losses into consideration, completes the palette of solvers.

## PERFORMANCE AND AUTOMATION

Users of CST MWS can take advantage of multiple processors in several ways — by using the parallel processing functionality, by which one simulation can use several CPUs on one mainboard, or through the distributed computing scheme, which can also utilize other computers in a network. For parameter studies and optimizations, runs with different parameter sets are allocated from, and results are collected and evaluated in one central front-end. New parameter sets for the next run of simulations are set up and distributed again. This scheme has been significantly improved in terms of network traffic, error tolerance and stability.

VBA macro language is also implemented. This, together with the COM/DCOM interface, makes the software accessible through other software packages, for example, if a user wants to implement his own evaluation or optimization schemes. Multi-run simulations, like monostatic RCS calculation, can be automated easily using either pre or user defined macros.

## **POST PROCESSING**

New post-processing features in version 2006 include the calculation of far fields over lossy ground, thus enabling the simulation of outdoor test ranges, a new broadband SPICE extraction scheme and average plots used for MRI applications.

The access to result data is facilitated through a sophisticated automatic post-processing scheme. Arbitrary goal functions can be derived for the two implemented automatic optimizers from a large, user extendable number of evaluations. For the visualization of parameter dependant result data, users can now employ tuning sliders.

## CONCLUSION

CST MWS version 2006 is a versatile simulator that offers users significantly increased value through its integration in CST STUDIO SUITE, The new multiple document interface and numerous improvements in all areas. The company uniquely enables access to time domain and frequency domain, on Cartesian or tetrahedral meshes through one interface, and its application range now spans from static to optical frequencies.

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# BROADBAND TACTICAL COMMUNICATIONS ANTENNAS

ilitary tactical communications require transportable radio systems that can be set up quickly in the field, under difficult conditions, to establish communication links. These radio systems are mounted in tactical operation centers (TOC), vehicles and shelters. Legacy antennas used in these systems operate primarily in the VHF or UHF frequency bands and have omni-directional radiation patterns. They are set up on the ground, mounted on vehicles, or attached to telescopic masts when the terrain requires additional height to establish a line-of-sight link.

To complement the latest generation of software-defined, multi-band/multi-mission radio

designs utilized by the military, new tactical communication antennas are needed, featuring wider frequency bandwidth than was previously available. The need for dual- and tri-band antennas is also becoming more commonplace, as the number of antennas mounted on military vehicles

continues to grow. The ability to accomplish multiple missions with a single aperture has become highly desirable. Chelton Microwave Sensor & Antenna Systems – Atlantic Division is designing wideband and multi-band antennas to address these requirements.

# **LEGACY ANTENNA DESIGNS**

In the 30 to 88 MHz Single Channel Ground and Airborne Radio System (SINCGARS) band, there are a number of legacy antenna designs that have been used over the years. These are mainly biconic antennas for mast-mounted applications and whip-style antennas for vehicle applications. Improved alternatives to these conventional approaches are the COM201B and COM231 antennas designed for military tactical SINCGARS applications (see *Table 1*). The COM201B is a ground-based antenna that can be deployed in a stand-alone, mastmounted, or suspended configuration (see *Figure 1*). The COM231 model is a vehicle-mounted antenna that includes a flexible spring

TABLE I

COM201B AND COM231 SPECIFICATIONS

Frequency band (MHz) 30 to 88

Gain (dBi) 2 nominal

VSWR 3.5:1 maximum

Impedance  $(\Omega)$  50

Power handling (W) 2000

Polarization vertical

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Fig. 1 Tripod-mounted CM201B antenna.

mount that enables the antenna to survive the rigors of driving on rough terrain. These antennas provide an omnidirectional radiation pattern in the horizontal or azimuth plane and a cardioid radiation pattern in the vertical or elevation plane, as shown in *Figure 2*.

The COM201B antenna is designed with quick deployment and ease of operation in mind. The unique tripod metal-tube leg structures that serve as both mount and electrical ground plane allow the antenna to be installed directly on the ground or on rooftops, bunkers and shelters. These tripod/ground-plane radials telescope and can either be removed or folded up parallel to the active element for transport.

Physical properties designed into the COM201B have the effect of decreasing the electrical reactance of the antenna's elements, which, in turn, increases the frequency range (bandwidth) over which the antenna can be efficiently operated. The COM201B

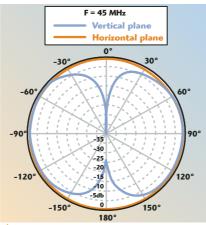


Fig. 2 Radiation patterns of the COM201B and COM231 antennas.

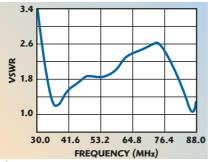


Fig. 3 VSWR of the COM201B antenna with matching network.

antenna's physical construction is such that the diameter-to-length is optimized to produce radiation across the 30 to 88 MHz frequency band, using a structure that has a reasonable size as well as effective radiation-efficiency characteristics. To make the antenna even more effective, the COM201B also includes a broadband, lumped element, impedance matching network. The network is located in the base of the lower radiating element near the feed point of the antenna. The network maximizes efficient transfer of power from the radio to the antenna field across the desired frequency range with a VSWR of less than 3.5:1, as shown in *Figure 3*.

The COM231 vehicle-mounted antenna uses the same design techniques as the COM201B, but whereas the COM201B is equipped with the tripod metal-leg structures to provide a ground plane, the COM231 model uses the vehicle it is mounted to as its ground plane. The impedance matching circuitry of the COM231 antenna is similar to that which is used in the COM201B antenna, but because the COM231 is used in a mobile environment, additional lightning protection

TABLE I	l				
COM237 SPECIFICATIONS					
Frequency band (MHz)	30 to 512				
Gain (dBi)	–2 typical				
VSWR	3:1				
Impedance $(\Omega)$	50				
Power handling (W)	150				
Polarization	vertical				

and high voltage protection circuitry is added. The COM231 is supplied with a standard military vehicle mount, as well as with a side-mount kit for attachment to shelters and some military vehicles.

Since the COM201B and COM231 antenna structures were specifically designed to deliver maximum low angle signals, their power on the horizon is greater than for other antennas of its type. In addition, the low loss impedance matching network and the higher length-to-diameter ratio of the antenna both work to increase the power gain on the horizon even further. Therefore, radio systems using these antennas can be expected to perform at distances greater than what is normally accepted to be radio line-of-sight using other antennas, and this has been confirmed in field trials by the US Army.

# NEXT GENERATION MULTI-BAND DESIGNS

The COM201B and COM231 antennas were used as a starting point for the development of a new series of antennas to cover the ultra broadband frequency range of 25 to 2500 MHz, as required for the next generation communication and electronic warfare applications. Using technology developed from these legacy antenna designs, new antennas have been designed for both dual- and tri-band applications.

One such new antenna is the COM237 model, which operates over the 30 to 512 MHz frequency band and complements the latest software-defined radios that are currently being procured by the military (see *Table 2*). This is a vehicle-mounted antenna that has the same mechanical footprint as the COM231 vehicular antenna (see *Figure 4*). It has a base section 32" long, which is 3" in diameter and the remainder has a 1.75" diameter. The overall length of the antenna is 75". This broadband operation is accomplished by integrating a UHF radiator into the

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Fig. 4 COM237 antenna mounted on a military vehicle.

same space as a VHF radiator and employing techniques to reduce the overall antenna length. The VHF section is an endfed monopole element operating in the 30 to 100 MHz range. The UHF section is a sleeve

dipole operating from 100 to 512 MHz. The COM237 can be supplied in either a one-RF or two-RF port configuration. When supplied as a one-RF port antenna, the COM237 can interface to a software-defined radio and take full advantage of its wideband operation. When configured with two RF ports, this antenna can support both VHF (SINCGARS) and UHF (EPLRS, for example) bands of operation simultaneously, thus minimizing the number of apertures installed on the vehicle.

Another next generation antenna is the COM235, a multi-band antenna that covers the VHF (30 to 100 MHz), UHF (100 to 512 MHz) and L-band (900 to 2500 MHz) frequency bands. The design of this model builds upon the COM237 dual-band design by adding an additional bi-cone radiator on top to address the L-band requirement. This can be accomplished in a physical package size that is 3.5" in diameter, with an overall height of 70". This antenna can be configured with three separate RF ports, or two of the elements can be combined through a diplexer to reduce the number of RF ports. When configured with three RF ports, the single antenna can be used for three distinct missions such as SINCGARS, EPLRS and JTIDS. The isolation between the bands of operation is sufficient to operate this way. When the elements are combined to a single RF port, the antenna can be used for wideband detection and jamming applications.

A COM236 model has also been developed for JTRS. The COM236 again features a VHF (30 to 100 MHz) radiating element, a UHF (100 to 512 MHz) radiating element and an L-band radiating element covering 900 to 1850 MHz. The COM236 outline is similar to the COM201B, featuring an upper radiating diameter of 1.5", with an additional seven inches in height to accommodate the L-band radiating element.

# **CONCLUSION**

New multi-band antenna designs are available to address wideband software-defined radio applications as well as multi-mission requirements. These multi-band antennas feature improved bandwidth, radiation efficiency and power handling performance in the same basic outline as legacy single-band antennas. The antennas are used in military tactical communications applications, as well as in some broadband detection and jamming applications.

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# New High Power SMT Power Dividers/ Combiners

₹he Wilkinson divider has long been popular with RF designers. In recent years, off-the-shelf, surface-mount technology (SMT) components of this type have become available and provide tremendous cost savings in high volume pick and place manufacturing. Some of its applications are found in power amplifier design and modern communication systems. Many applications employing the Wilkinson structure cannot be enhanced by the use of any available surface-mount or tab-contact component solution. However, through the use of new materials and manufacturing processes with new design techniques, these SMT power dividers provide better performance and wider applicability. These innovative, ceramic-based planar components now permit the realization of smaller and more integrated power amplifiers that can tolerate worse internal and external source and load mismatches.

The Wilkinson power divider has been well documented and used for many years as a building block in many RF and microwave splitting and combining networks. In power amplifier applications, the power divider allows single, large and expensive, high power amplifiers to be replaced with several, smaller and lower cost, power amplifiers. In addition, this power dividing/combining technique takes advantage of the linear operating region of the high power amplifiers, thus reducing intermodulation distortion.

The Wilkinson in-phase divider utilizes  $\lambda/4$  transmission lines for impedance matching and an isolation resistor connected between each end of the  $\lambda/4$  section(s). In an N-way power divider, the power division depends on the number N of output ports. The magnitude of the power division is calculated using the equation  $10\log(1/N)$ . The use of the resistors allows the ports to be matched. In addition, it isolates the output ports from one another at the center frequency.

When used as a power divider, the input signal is split into signals of equal amplitude

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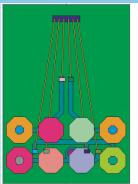
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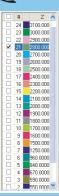
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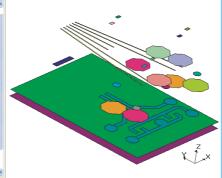
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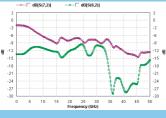


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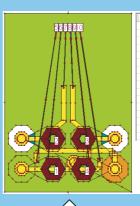
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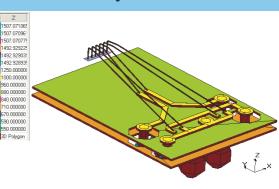


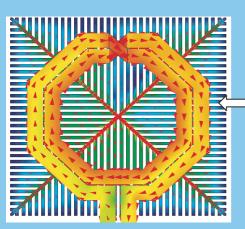
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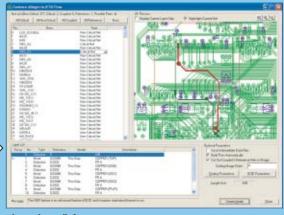


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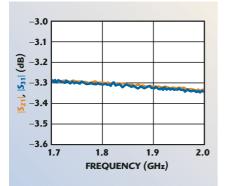
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		TA	BLE I			
TYPICAL PERFORMANCE OF THE HYBRIX® GENERATION OF SMT POWER DIVIDERS						
	Two-way VSWR	Power (W)	Three-way VSWR	Power (W)		
	1.2	50	1.2	35		
	1.4	50	1.4	35		
	1.5	34	1.5	24		
	1.7	19	1.7	14		
	2.0	13	2.0	9		



▲ Fig. 1 Amplitude balance and insertion loss of a two-way power divider, including its test board.

and phase at the output ports. As a result, each terminal of the isolation resistor will be at the same potential and, consequently, no potential difference and no voltage drop. A mismatch at one of the output ports will not affect the other outputs. This is due to the 180° phase difference when the reflected signal appears at the opposite end of the isolation resistor. On the other hand, combining signals of unequal magnitudes will cause a voltage drop across the resistor, thus dissipating power.

The general performance characteristics of a power divider are isolation, amplitude balance, phase balance, VSWR, power handling capability and insertion loss. As an indication of high performance, a power divider has a typical isolation of 20 dB and the higher the isolation, the less chance of leakage between the output ports. Generally, the isolation will degrade at higher frequencies.

Amplitude and phase balances, sometimes referred to as amplitude and phase tracking, are also important indications. These are simply the amplitude and phase differences between the powers at the output ports. Amplitude balance typically increases

with the number of output ports. The VSWR indicates how well the input and output ports are matched to each other and to external connections. In addition, the power handling capability is of high importance to the designer. The rating is usually given for

matched conditions or matched power rating. For an unmatched system, the power handling is dependent upon the internal resistors used. Wilkinson power dividers are typically fabricated as a printed structure on Teflon-based material using chip resistors. In recent years, SMT versions have become readily available. The latest generation of SMT Wilkinson power dividers, fabricated on ceramic substrates, has recently become available and provides tremendous increases in performance, compared to SMT power dividers of previous generations. By utilizing a ceramic substrate, these products allow for higher thermal dissipation as opposed to those created with Teflon-based materials. **Table 1** illustrates the power performance of the new power dividers under different matching conditions.

# **TWO-WAY POWER DIVIDERS**

The HybriX® family of the SMT high power dividers is built on alumina, using thick film resistors and advanced screen-printing techniques, allowing better performance and wider applicability. In addition, smaller and more integrated circuits can be realized. These new generations of SMT high power dividers provide very low insertion loss, excellent return loss, very low VSWR, higher thermal dissipation and high power handling capacity up to 50 W. Typical measured S-parameter data for a two-way divider are shown in **Fig**ures 1 and 2.

## **THREE-WAY POWER DIVIDERS**

A single-stage three-way device can facilitate the development of power amplifiers with lower loss and more compact layouts. The three-way Wilkinson dividers in this new family

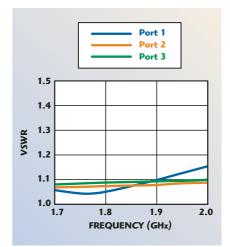
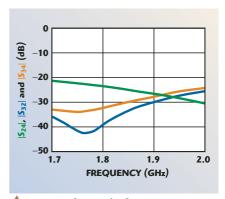


Fig. 2 VSWR of a two-way power divider.



▲ Fig. 3 Isolation of a three-way power divider.

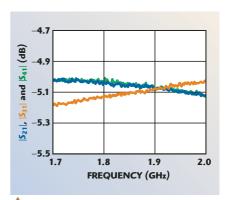


Fig. 4 Insertion loss of a three-way power divider, including its test board.

of products are fabricated as completely planar microstrip structures. Typical measured RF performances for the HybriX three-way power divider, within the frequency range from 1.7 to 2 GHz, are shown in *Figures 3* to 5. For these measurements, all the devices were operated as power dividers, that is, port 1 was the input and ports 2, 3 and 4 were the outputs. The test fixture dissipation and mismatch losses have not been de-



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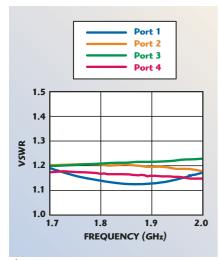


Fig. 5 VSWR of a three-way power divider.

embedded from these measured results. When referenced to 50  $\Omega$ , the total loss of the test board is approximately in the range of 0.08 to 0.15 dB.

### **FOUR-WAY POWER DIVIDERS**

The four-way power dividers expand the product line offering and are designed using the same design

and process methodology as the three-way dividers described earlier. The RF performances for the fourway, in-phase power dividers are similar to those of the other dividers. To that end, they have a very low insertion loss, excellent isolation, low VSWR, high power rating, excellent thermal dissipation, and very good amplitude and phase balance.

### **HIGH POWER TESTING**

These high power SMT power dividers were tested by Modelithics Inc. to determine their power handling capabilities. The test conditions were as follows: The power divider was tested at increasing discrete power levels, each of 15 minutes duration. The base plate was held at a constant temperature of 85°C during the measurement. The S-parameter measurements were made between every increase in power level. The base temperature was monitored using a temperature probe, and the resistor temperature using an IR camera system. The parts met or exceeded the rated power.

### CONCLUSION

Power dividers are commonplace in the RF world. Through the use of new materials and manufacturing processes together with new design techniques, power dividers have been reinvented. The latest generation of SMT high power dividers provides excellent isolation, low VSWR, low insertion loss, excellent return loss, high power rating, and very good amplitude and phase balance. In addition, their smaller size reduces the circuit area, thus allowing design flexibility.

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2	4.0-27	1.0	18	0.5	PS2-50
2	0.5-18	1.7	16	0.6	PS2-20
2	0.5-20	2.2	12	0.4	PS2-24
3	2.0-18	1.5	18	0.4	PS3-50
3	2.0-20	1.8	16	0.5	PS3-51
4	1.0-27	4.5	15	0.8	PS4-51
4	5.0-27	1.8	16	0.5	PS4-50
4	0.5-18	4.0	16	0.5	PS4-17
4	2.0-18	1.8	17	0.5	PS4-19
8	0.5-6	1.5	20	0.4	PS8-12
8	2.0-18	2.2	15	0.6	PS8-13
8	3.0-15	1.3	15	0.5	PS8-15

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0.8-2.2	0.35	1.00	22	1.20:1	CS*-02A
1.0-4.0	0.35	0.50	23	1.20:1	CS*-04
2.0-8.0	0.35	0.40	20	1.25:1	CS*-09
0.5-12.0	1.00	0.80	15	1.50:1	CS*-19
4.0-12.4	0.50	0.40	17	1.30:1	CS*-14
			2-12 12-18	3 GHz	
1.0-18.0	0.90	0.50	15 12	1.50:1	CS*-18
2.0-18.0	0.80	0.50	15 12	1.50:1	CS*-15
			4-12 12-18	3 GHz	
4.0-18.0	0.60	0.50	15 12	1.40:1	CS*-16
8.0-20.0	1.00	0.80	12 12	1.50:1	CS*-21

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MFC2941-12	290 to 410	0.5 to 24	-110	+12
MFC1926-12	190 to 260	0.5 to 12	-114	+12
MFC4151-12	410 to 510	0.5 to 15	-112	+12
MFC6170-5	610 to 790	0.5 to 5	-113	+5
MFC7995-5	790 to 950	0.5 to 15	-114	+5
MFC8192-5	810 to 920	0.5 to 5	-106	+5
MFC81100-5	810 to 1000	0.5 to 10	-105	+5
MFC102110-5	1020 to 1100	0.5 to 5	-106	+5
MFC-S-1000	1000 to 2100	1 to 18	-99	+12
MFC138165-5	1380 to 1650	0.5 to 24	-102	+5
MFC170195-5	1700 to 1950	0.5 to 10	-104	+5
DCRO Series				
DCR0127175-5	1270 to 1750	0.5 to 18	-107	+5
DCR0128177-12	1280 to 1775	0.5 to 24	-112	+12
DCRO175260-5	1750 to 2600	0.5 to 15	-96	+5
DCRO204235-8	2040 to 2350	0.5 to 24	-109	+8
DCRO219250-8	2190 to 2500	0.5 to 24	-106	+8
DCRO243298-5	2430 to 2980	0.5 to 15	-101	+5
DCRO250300-10	2500 to 3000	0.5 to 24	-107	+10
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Standard power output for the radio's transmitter is 30.5, 28.5 and 25.5 dBm for the L6, U6 and 11 GHz frequency bands, respectively. A high power option of 33.5 dBm is available for the L6 GHz band. There is 20 dB of power output control per ATPC/MTPC (1 dB steps).

The unit utilizes 128QAM modulation with a channel bandwidth of 30 MHz. The transmit frequency is determined from a synthesized internal oscillator and features a stability of less than  $\pm 10$  ppm. The receive signal level (RSL) at  $10^{-6}$  is -69 dBm with a system gain

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	ZASW-2-50DR ZASWA-2-50DR	DC-5 DC-5	90 90	1.7 1.7	20 20	(Qty. 1-9) 89.95 89.95
•	Supply voltage +5V, Switching time 10ns Reflective Absor	sec (typ).	control.		3x3mm Mini-Circuits Low Profile (MCLE	

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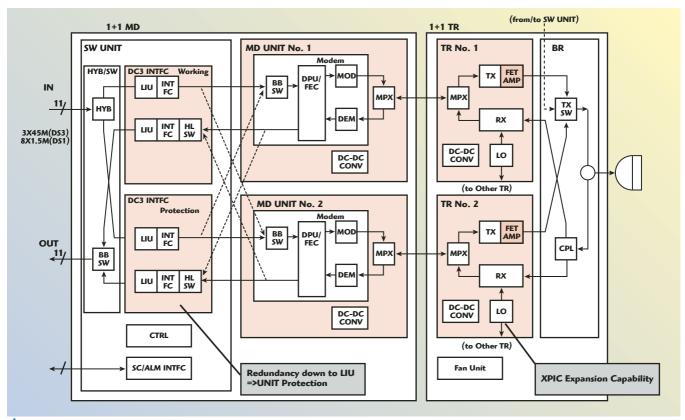


Fig. 1 NLite Lx functional block diagram.

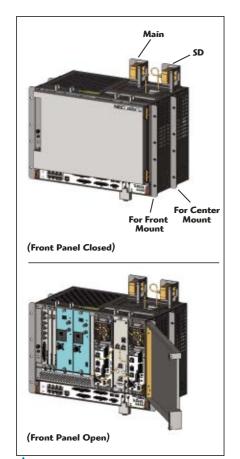


Fig. 2 The L6G/3xDS3 NLite Lx radio system.

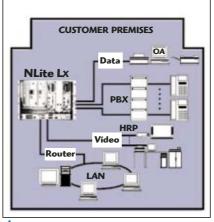


Fig. 3 A typical NLite Lx application.

of 99.5 dB at L6 GHz with standard power. Residual BER is less than  $10^{-12}$ . *Figure 1* shows the NLite Lx system's functional block diagram.

The flexible architecture of the NLite Lx allows for split or all indoor configurations. The new microwave system, shown in *Figure 2*, supports high performance broadband transmission services for interconnections within cellular networks. In addition, the new system features independent private LAN connections between backbone networks and users' premises (see *Figure 3*).

Similar to other members of the NLite family, the NLite Lx radio system is compliant with SNMP protocol network management and centralized network management, and operates on standard platforms such as Windows NT or UNIX operating systems. Additional products in the NLite family include the NLite L series for small and medium capacity plus an economically friendly footprint, the NLite series for small and medium capacity with T1 plus Ethernet capability, and the NLite 155 series to satisfy medium and large capacity demands. For additional information and the system's full specifications, contact NEC America Inc.

NEC America Inc., Irving, TX (888) NECWAVE (632-9283), www.necwaye.com.

RS No. 304

CHECK OUT OUR WEB SITE AT www.mwjournal.com





# 2006 International Conference on Ultra-Wideband FINAL CALL FOR PAPERS



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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).

Prospective authors are invited to submit Summaries of their work (6 pages maximum, PDF format) emphasizing their contribution beyond the present state of the art. Submission of a paper implies that at least one of the authors will have a full registration to the Conference on acceptance of the paper. Each registered author can present a maximum of three papers. All accepted papers will be published by the IEEE in the Conference Proceedings and included in IEEE Xplore. There will be a student paper contest. See the conference website for further details.

# **Antennas and Propagation:**

UWB antennas Field trials & measurements

Channel measurements & modeling

# Systems and signal processing:

Modulation & detection Interference & capacity
System architectures Coding & decoding
Synchronization Multiple access schemes
Ranging & localization

# Hardware architecture and Implementation:

RF modules Low power consumption techniques

Pulse generation & detection OFDM implementations Integrated circuit design Circuits & Systems

## Regulatory issues:

Spectral management Signal modeling
Measurement for type approval Co-existence

# **UWB Applications:**

Wireless PAN Sensing
Positioning Radar

Tools for system analysis Consumer electronics

Home networking Wireless USB, Wireless Firewire

# **Important Dates For Authors:**

Submission of 6-page Summary: 7 March 2006 Notification of acceptance: 2 May 2006 Final Manuscript (6-page max) due: 9 July 2006

Workshop proposals must be received by 11 February 2006. Further information will be posted on the ICUWB2006 website: http://www.ICUWB2006.org

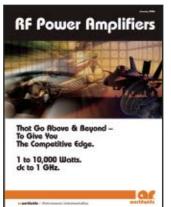






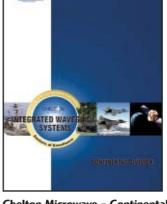


AR Worldwide,



# RF Power Amplifiers Brochure

This revised amplifiers brochure features the company's wide range of RF power amplifiers available. The brochure highlights the "A" and "W" series amplifiers that cover 1 to 10,000 W and DC to 1 GHz. Product photographs, descriptions, specification and performance graphs are included for each model.

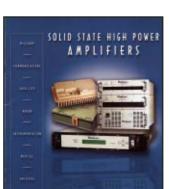


# Product and Capabilities Brochure

This 12-page brochure highlights the product lines and capabilities of Chelton Microwave – Continental Division. From design and manufacture of waveguide components and complex integrated waveguide assemblies to repair and overhaul of the same, this division offers complete solutions for military and aerospace applications.

Chelton Microwave – Continental Division, Exeter, NH (603) 775-5200, www.cheltonmicrowave.com.

RS No. 311



COMITECH ST.

# **Amplifiers Brochure**

This brochure highlights the company's solid-state high power amplifiers that operate in frequency ranges from 1 MHz through 3 GHz, with output power levels ranging from 5 W to over 30 kW. The company designs, develops and manufactures amplifiers to serve a variety of domestic and international markets including defense, wireless and satellite communications, cellular and PCS instrumentation, electromagnetic compatibility testing and medical systems.

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

Souderton, PA (215) 723-8181, www.ar-worldwide.com.

RS No. 312

RS No. 310



## **Product Brochure**

This brochure highlights the company's narrowband frequency synthesizer products. Featured products include the MFS, DFS and WMFS series that offer reliable integrated system synthesizers. Also highlighted are the SPDRO, SF-DRO and PSDRO series products that offer phase noise efficiency with broad performance features. The products are targeted for applications such as radar systems, EW, electronic surveillance, avionics, instrumentation, point-to-point digital radio, fiber optic cable networks and SATCOM.

Elcom Technologies, Rockleigh, NJ (201) 767-8030, www.elcom-tech.com.

RS No. 313



# Frequency Synthesizer Data Sheet

This data sheet provides complete detail on the company's high speed direct analog frequency synthesizer, model MW 15131HP. This model is a full band synthesizer designed for OEMs requiring phase and frequency coherent synthesis. With 1 microsec settling time from any frequency to any frequency, this synthesizer covers the full frequency range of 2 to 18 GHz (option: 0.5 to 18 GHz).

Elisra Electronic Systems Ltd., Microwave Division, Bene Beraq, Israel 972-3-6175655, www.mw-elisra.com.

RS No. 314



# Filter Catalog

This new short form catalog features a sampling of the company's RF and microwave filter products to 40 GHz utilized in military, commercial and wireless applications. The catalog also highlights some of the company's diverse filter design and manufacturing capabilities.

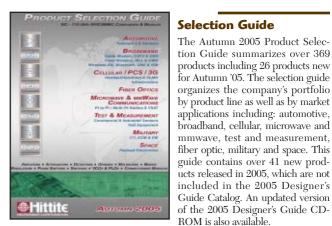
Eastern Wireless TeleComm Inc., Salisbury, MD (410) 749-3800, www.ewtfilters.com.



## **Quick Reference Guide**

The Autumn 2005 edition Quick Reference Guide now consists of two separate brochures, one for the discrete/MMIC product line and one for the switch product line. The discrete catalog features several new broadband MMICs, and the company's new line of packaged C-band amplifiers. The switch catalog includes several new switch products as well for WLAN/WiMAX applications. Both brochures include a special section covering WiMAX product offerings.

Filtronic Compound Semiconductors Ltd., Newton Aycliffe, County Durham, UK +44 (0) 1325 306 880, www.filtronic.com. RS No. 316



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

RS No. 317

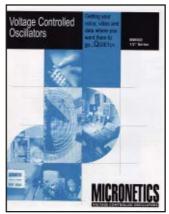


# Blindmate Interconnect Brochure

This brochure highlights the company's variety of products for use in microelectronic applications. These products include high performance microwave connectors, hermetic connectors and machining services to both the military and commercial markets. The company offers complete manufacturing capability in-house to meet the production requirements of its customers.

Micro-Mode Products Inc., El Cajon, CA (619) 449-3844, www.micromode.com.

RS No. 318



# Voltage-controlled Oscillators

This brochure highlights the company's voltage-controlled oscillators (VCO) while featuring the MW500 series of 0.50" VCOs. The MW500 series is designed to make it easier to find and focus on the exact VCOs needed to meet frequency requirements ranging from 50 MHz to 7.5 GHz. The MW500 series offers rugged design and reliable performance characteristics that make them ideal for use in today's real world applications.

Micronetics Voltage Controlled Oscillators, Hudson, NH (603) 579-0900, www.micronetics.com.

RS No. 319

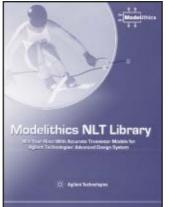


# Microwave Diode Packages

This paper discusses the different types of microwave diode packages available, the attributes of each, and the effects one might expect when used in some common circuit applications. The paper highlights parasitics, circuit implications of package parasitics and package categories that include microwave, surface-mount and thru hole.

Microsemi Lowell, Lowell, MA (978) 442-5600, www.microsemi.com.

RS No. 320



# **Product Brochure**

This product brochure describes a comprehensive and feature rich nonlinear Transistor Library for improved microwave design simulation with Agilent Technologies' Advanced Design System. The NLT Library delivers high accuracy and well-documented models with features like substrate scalability and extensive measurement validations for high power and low noise designs.

Modelithics Inc., Tampa, FL (888) 359-6359, www.modelithics.com.





Rogers Corp., Rogers, CT (860) 779-5597, www.rogerscorporation.com.

### **Product Brochure**

The "Handset Solutions" product brochure showcases the company's wide range of specialty materials for handset applications. This literature features high performance foams, electroluminescent lighting and advanced circuit materials. These materials are used in a multitude of handheld device applications. For ease of use, each specialty material is color-coded to correspond to a table listing both its features and benefits.



Sage Laboratories Inc., Hudson, NH (603) 459-1600, www.sagelabs.com.

RS No. 323

component products



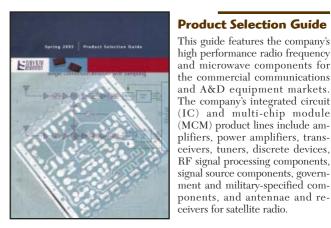


# Antenna Measurement Systems and Reference Antennas

Satimo, a provider of antenna measurement systems, offers a full line of turnkey systems, services and equipment for antenna testing and NDT. This updated catalog includes information and specifications for standard products, as well as reference information and examples of customized antenna test solutions.

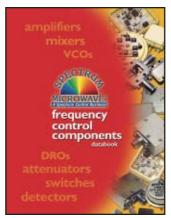
Courtaboeuf, France +33 1 69290247, www.satimo.com.

RS No. 324



Sirenza Microdevices Inc. Broomfield, CO (303) 327-3030, www.sirenza.com.

RS No. 325

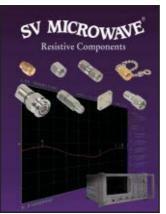


# Frequency Control Components Databook

This databook details the company's full line of RF amplifiers, low phase noise amplifiers, RF mixers, VCOs, DROs, limiters, limiting amps, detectors, attenuators and switches. Designed to reduce a reader's component search and selection time, the 900-page plus databook outlines product characteristics and features, as well as graphed performance data and various packaging options.

Spectrum Microwave Inc., Palm Bay, FL (321) 727-1838, www.specwave.com.

RS No. 326



# **Resistive Components Catalog**

This 24-page catalog provides specifications and outline drawings for some of the company's most popular fixed coaxial and chip attenuators as well as coaxial terminations. QPL attenuators to MIL-A-3933/14, /16, /18 and /25 are included, as well as QPL terminations to M39030/3. Also included are short circuit terminations and resistance cards

SV Microwave Inc., West Palm Beach, FL (561) 840-1800, www.svmicrowave.com.

# CATALOG UPDATE

# Microwave Switches Selection Guide Failsafe Latching SPOT Up to 8T High Power Transfer DC to 25.5 GHz STELEDWE HILLYS STELEDWE HILLYS AT REAM MICROWAYE SWITCHING STELEDWE HILLYS AT REAM MICROWAYE SWITCHING

## Microwave Switch Guide

This guide features details in tabular form of 20 switch families, information on applications and a glossary of terms providing a quick and simple method of product selection. It provides detailed information on relays, transfer switches and single-pole and multi-pole switches up to 26.5 GHz. Data published includes detailed mechanical drawings, charts showing insertion loss, isolation, return loss and RF power handling capabilities.

Teledyne Electronics and Communications, Quickborn, Germany +49 (0) 4106 7684-0, www.teledyne-europe.com.

RS No. 328

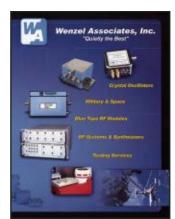


## Test Cable Brochure

This updated brochure features the company's SilverLine<sup>TM</sup> test cables that are utilized by original equipment manufacturers of RF and microwave components and subsystems in production test, R&D and quality control. The revised brochure adds several new connectors (BNC plug, N male right angle, 3.5 mm ruggedized male), adapters (SMA plug/QMA female, SMA jack/QMA female) and a handy QMA extraction tool. A OneTurn<sup>TM</sup> connect/disconnect N male connector is also offered.

Times Microwave Systems,
Wallingford, CT (978) 887-3033, www.timesmicrowave.com.

RS No. 329



# **Product Brochure**

This brochure highlights the company's manufacture of precision crystal oscillators and related radio frequency devices for the communications, navigation, military and test equipment markets. In addition to components, the company manufactures a variety of high performance instruments and subsystems.

Wenzel Associates Inc., Austin, TX (512) 835-2038, www.wenzel.com.

RS No. 330

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# **New Waves:** Radar/Antennas MMMM

# ■ Spectrum Analyzer



The model N1996A is a compact, high performance spectrum analyzer (CSA) available in 3 and 6 GHz models and designed for use in a wide array of industries. This CSA enables R&D and manufacturing engineers and technicians to make precision RF measurements with speed, ease and confidence. The CSA incorporates a full-featured, general-purpose spectrum analyzer with an internal VSWR bridge and tracking generator. This allows customers to easily and accurately characterize single- and dual-port devices. Price: under \$10,000.

Agilent Technologies Inc., Palo Alto, CA (800) 829-4444, www.agilent.com.

RS No. 250

# ■ RF Connector

The Type N is a medium-sized RF connector used to satisfy larger coaxial cable types. This



durable and weatherproof connector operates in a frequency range from DC to 18 GHz and can withstand shock vibration. Applications include: an-

tennas, aerospace, microwave radio, WLAN, PCS, cellular, radar and surge protection.

Christensen Smith Tran (CST), Sparks, NV (775) 331-4866, www.cstcable.com.

RS No. 216

## Rotary Joints



The company's range of rotary waveguide joints has been expanded with the addition of a series of L-style models that are particularly suitable for outdoor applications such as SATCOM or military-radar systems. As well as offering IP65 environmental protection, the AM-RJL series rotary joints feature a rugged, lightweight aluminum construction, finished in Alochrom satin black epoxy paint. Covering the frequency range 5.8 to 15 GHz, the L-style joints are available in five different waveguide sizes from WR-137 to WR-62 and can be specified with or without mounting flanges.

Link Microtek Ltd., Basingstoke, UK +44 (0) 1256 355771, www.linkmicrotek.com.

RS No. 217

# ■ High Efficiency Antenna

The model RP2-54-N is a broadband high efficiency 2' diameter antenna that was designed



for use in the point-to-point unlicensed 5 GHz WLAN communications band. This model operates in a frequency range from 5.25 to 5.85 GHz and in the licensed Public Safety band from

4.94 to 4.99 GHz. The reflector is precision spun aluminum. The mount includes azimuth/elevation fine adjustment capability and is designed to attach to a range of mast pipe sizes from 1.9" to 4.5" in diameter.

mWAVE Industries LLC, Gorham, ME (207) 857-3083, www.mwavellc.com.

Circle No. 218

# Parabolic Antennas



The SPX-3.5NS series of antennas covers a frequency range of 3.3 to 3.6 GHz or 3.5 to 3.8 GHz. Providing coverage down to 3.3 GHz makes these reliable parabolic dishes usable in numerous international bands including China. The standard SPX-3.5NS antennas now cover 3.3 to 3.6 GHz and can be ordered "tuned" to the 3.5 to 3.8 GHz bands when required. These antennas are available in diameters from 2 to 8 feet and accompany a three-year warranty.

Radio Waves Inc., N. Billerica, MA (978) 459-8800, www.radiowavesinc.com.

RS No. 219

### Hemi Antenna

This low profile redesigned Hemi antenna offers reliable wide area coverage, both indoors



and outdoors by providing good radiation patterns for areas using either circular or linear polarization. These linearly polarized Hemi antennas

operate at 800 and 900 MHz. This antenna features the same coverage pattern associated with the standard hemi, but with linear polarization. These "Hemi" antennas are well suited for indoor use, but because of the radome to back plate weather seal, are very well suited for outdoor applications.

Astron Wireless Technologies Inc., Sterling, VA (703) 450-5517, www.astronwireless.com.

RS No. 254

### Advanced Positioner Controller



The AL-4806-3C series is a versatile, simple-to-operate positioner controller, offering full control of positioning subsystems in automated antenna measurement systems. It provides fully programmable control of antenna, test and target positioners, and is designed to provide the user with advanced control, while maintaining an intuitive interface for manual operations. Advanced microprocessor architecture assures optimal data throughput for automated data collections. Manual operation is a simple combination of axis selection and a user-adjustable control knob.

Orbit/FR Inc., Horsham, PA (215) 674-5100, www.orbitfr.com.

RS No. 255

## Parabolic Antenna

The model QRP-T0024Z01 is a broadband prime focus parabolic antenna. This single an-



tenna covers a frequency range from 18 to 40 GHz with 40 dB nominal gain at center frequency. The maximum VSWR is 1.35. The power handling is 10 W for

CW mode with a K-connector and 800 W for CW and 5 kW for peak power with a WRD180c24 connection. This antenna is available with gain options ranging from 30 to 55 dB.

QuinStar Technology Inc., Torrance, CA (310) 320-1111, www.quinstar.com.

# 300kHz to 14GHz AMPLIFIERS



ZX60 is a new breed of SMA amplifiers small in size, small in price, and big on performance! Within this versatile family, you'll find models with broad and ultra-broad bandwidths spanning up to 14GHz, very flat response, high isolation, noise figure as low as 0.4dB, and output power up to +24.0dBm. Unit-to-unit performance repeatability is very high, thanks to our exclusive patented Unibody construction. These easily mountable amplifiers are the perfect choice for your military and commercial needs. So contact Mini-Circuits today. Our team is ready to handle your requirements from quick off-the-shelf shipments to custom solutions!

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-	(GHz)	(dB) Typ.	(dB) Typ.	(dBm) Typ.	Comp. Typ.	Volts (V)	(mA) Max.	\$ea. (1-9)	
Figure 1	h: 0.74" x (W)	1.18" x (	H) 0.46						
ZX60-2510M	0.5-2.5	12.9	5.4	+28.8	17.1	5.0	95	59.95	
ZX60-2514M	0.5-2.5	16.4	4.8	+30.3	18.3	5.0	90	59.95	
ZX60-2522M	0.5-2.5	23.5	3.0	+30.6	18.0	5.0	95	59.95	
ZX60-3011	0.4-3.0	11.5	1.7	+31.0	21.0	12.0	120	139.95	
ZX60-3018G	0.02-3.0	20.0	2.7	+25.0	11.8	12.0	45	49.95	
ZX60-4016E	0.02-4.0	18.0	3.9	+30.0	16.5	12.0	75	49.95	
ZX60-5916M	1.5-5.9	18.0	6.4	+28.3	15.7	5.0	96	59.95	
ZX60-6013E	0.02-6.0	14.0	3.3	+28.7	10.3	12.0	50	49.95	
ZX60-8008E	0.02-8.0	9.0	4.1	+24.0	9.3	12.0	50	49.95	
ZX60-14012L	0.0003-14.0	12.0	5.5	+20.0	11.0	12.0	68	172.95	
AL .									
Carried Length	gth: 1.20" x (W	') 1.18" x	(H) 0.	46"					
ZX60-1215LN	0.8-1.4	15.5	0.4	+27.5	12.5	12.0	50	149.95	
ZX60-1614LN	1.217-1.620	14.0	0.5	+30.0	13.5	12.0	50	149.95	
ZX60-2411BM	0.8-2.4	11.5	3.5	45.0	24.0	5.0	360	119.95	
ZX60-2531M	0.5-2.5	35.0	3.5	+26.1	16.1	5.0	130	64.95	
ZX60-2534M	0.5-2.5	38.0	3.1	+30.0	15.9	5.0	185	64.95	
		U.	S.Pate	nt # 6,79	90,049				

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#### COMPONENTS

#### Absorptive PIN Diode Switch

The model SW2AD-23 is an absorptive SP2T PIN diode switch. This model provides  $55~\mathrm{dB}$ 



of isolation over the frequency range of 0.3 to 18 GHz with 3.5 dB insertion loss and 1.7 VSWR. The TTL driver is internal and is pow-

ered by  $\pm 5$  V. The housing is  $1.35" \times 1.75" \times 0.5"$  with SMA female connectors at all ports.

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

RS No. 229

#### Quick Connect Adapters

These Quick Connect adapters provide efficiency and save time in test and measurement



applications by allowing for a complete connection in about one turn of the male coupling nut. The

new family of adapters that feature Quick Connect include 7/16 DIN male to type N male,

## WANTED

#### **Production Manager**

Duties include supervision of assembly team, scheduling and workflow management. Must have management skills and experience in manufacturing is desired. Salary commensurate with experience.

We are also seeking Chip and Wire Assemblers as well as Test Technicians.



Reactel, Incorporated 301-519-3660

jobs@reactel.com

7/16 DIN male to type N female, SMA male to type N female and SMA male to SMA female. The SMA units operate in the DC to 18 GHz range while the 7/16 DIN units operate from DC to 7.5 GHz. All units feature low VSWR. **Aeroflex/Inmet**,

Ann Arbor, MI (734) 426-5553, www.aeroflex-inmet.com.

RS No. 220

#### SP2T Reflective Switch

The model SWN-RAYR-2DR is a single-pole, two-throw, reflective switch module with op-



tions HPE2W, HS30NS and LVT25MV. It offers a low insertion loss of 1 dB typical, and an integral TTL driver that is designed for ultra low

video transient, high power and operates between 600 to 1300 MHz.

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

RS No. 221

#### Directional Couplers

These directional coupler octave models operate in a 0.5 to 26.5 GHz frequency range. The



couplers provide a convenient and accurate means for sampling microwave energy, and are ideally suited for monitoring incident

and reflected power. This directional coupler family consists of three-port directional couplers, four-port bi-directional couplers, four-port dual directional couplers, four-port high power directional couplers and four-port directional detectors. All models offer high performance and quick delivery.

Microwave Communications Laboratories Inc., Saint Petersburg, FL (727) 344-6254, www.mcli.com.

RS No. 226

CSIRO ICT Centre Sydney, Australia



Vacancy

#### RF & Digital Engineers

Wireless Technology Laboratory Ref: 2005/1522 & 2005/1518

For selection documentation and details on how to apply visit

www.csiro.au/careers
Alternatively contact +61 1300 301 509

Australian Science, Australia's Future

#### E-band Diplexer

The E-band diplexer consists of two waveguide bandpass filters specially designed to pass a rel-



atively wide portion of the spectrum, from 71 to 76 GHz and 81 to 86 GHz. Utilizing the propagation

of a specific combination of modes, the diplexer is designed to provide a minimum of 15 dB return loss without any tuning. Waveguide interface flanges are WR-12.

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

RS No. 223

#### Flexible Cables

The CBL series of rugged, triple-shielded flexible cables is ideal for laboratory and in-field



measurement applications requiring low insertion loss from DC to 18 GHz. These

cables deliver high performance levels while withstanding 20,000 flexures without any failures. This series is available from stock in a variety of lengths and male connector types, including SMA to SMA, SMA to type N and type N to type N connectors. Price: \$69.95 each (1–9). Delivery: available from stock.

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

RS No. 227

#### Four-channel Switch Bank

The model 4IFA-7000/10000-SR is a four-channel switch bank with channels at 7, 8, 9



and 10 GHz. The bank features 70 dB stopbands and a VSWR of 1.5. A m p l i t u d e matching of ±1 dB was specified

for each channel. Size:  $2.75\times1.75\times0.50$  package with SMA female connectors.

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

RS No. 225

#### Threshold Detector/Coupler/Switch

The model TDCS-4T-10F-HP is an integrated threshold detector, 17 dB coupler and SPDT



PIN diode switch. This device operates from 9 to 10.5 GHz (other frequency ranges are also available), with an insertion loss of 2 dB maximum, VSWR of

1.5 maximum, 2 W average RF input power handling capability and TTL threshold output. The TDCS-4T-10F-HP is designed to operate in harsh environments with stability over temperature and frequency. Size:  $1.5" \times 1.2" \times 0.40$ !

Planar Monolithics Industries, Frederick, MD (301) 662-4700, www.planarmonolithics.com.

RS No. 228

#### Protective Dust Caps



The continuing development of the QN snap-on connectors product range sees the addition of QN protective dust caps in both male and female versions. Both feature an attachment cord to pre-

vent the cap from being lost when not in use. The QN range is available with 50  $\Omega$  impedance for frequency ranges up to 11 GHz. Its snap-on coupling mechanism provides a fast, reliable, user friendly, consistent mate.

Radiall, Rosny Šous Bois,

Paris, France +33 1 49 35 35 35, www.radiall.com.

RS No. 230

#### ■ Compact Diplexer

The model 2DP-900/1750-00 is a compact diplexer with minimum passbands of DC to 900 MHz and 1750 to 2300 MHz. Insertion loss mea-



sures  $0.5~\mathrm{dB}$  in the low band and  $0.7~\mathrm{dB}$  in the high band with passband VSWR less than  $1.5~\mathrm{across}$  the entire unit. Channel-to-channel isolation is greater than  $50~\mathrm{dB}$ , and the return loss is greater than  $15~\mathrm{dB}$  in each band.

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

RS No. 231

#### ■ High Power Circulators/Isolators

The SMC series of surface-mount coplanar circulators and isolators operates from 800 to 2500 MHz. These circulators are designed for high



power applications and are distinguished by good high power performance in congested multi-carrier environments. Models are available in typical bandwidths of 10 to 15 percent with isolation > 22 dB and insertion loss < 0.35 dB. Size: 1" square.

Renaissance Electronics Corp.,

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

RS No. 232

#### ■ No-solder Connector

The model EZ-200-NMH-D (3190-1918) is an improved no-solder EZ crimp connector for LMR-200 and LMR-200-LLPL. This model fea-



tures a combination hex/knurl coupling nut that allows tightening by hand or with a wrench, and tri-metal plating instead of silver that eliminates tarnishing while providing good electrical performance. This model offers a ridged landing area on the aft

end for better grip and sealing of the heat shrink boot to provide improved strain relief and weather sealing, and good VSWR performance to 8 GHz on both LMR-200 and LMR-200-LLPL. Price: \$11.80.

Times Microwave Systems,

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

RS No. 234

#### **AMPLIFIERS**

#### High Power Amplifier

The model 50AMP10M100-40-36 is a broadband, high power amplifier that operates in a frequency range from 10 to 100 MHz and is designed



for defense, wireless and commercial radio applications. This model offers a gain of 40 dB minimum and flatness better than ±2 dB that allows a minimum output power at one

dB compression of 36 dBm. This amplifier is supplied with  $\hat{S}MA(f)$  input and output connectors and draws less than 1.2A in DC current from a +15 V supply. Size:  $<2.5"\times8"\times1.2"$ . Delivery: available from stock.

Amplical Corp.,

Verona, NJ (201) 919-2088, www.amplical.com.

RS No. 235

#### ■ Ku-band Power Amplifiers

The model MPC4-1220 is a Ku-band power amplifier that offers a multitude of configurations to meet specific needs. The models are defined



by the communication bands, have RF power levels of 45, 55 or 65 W, with optional features 04 (L-band block upconverter) and 09 (28 or 48 V DC power supply). This series is ideal for SATCOM systems serving military and commercial airborne and mobile platforms. Key features include: discrete mute control, 115/230 V AC power supply, monitor

and control processor, forward and reverse power monitor, and outdoor enclosure with forced air. Size: 10.3" × 8.98" × 10.27". Weight: 23.2 lbs.

Sophia Wireless Inc.,

Chantilly, VA (703) 961-9573, www.sophiawireless.com.

RS No. 240

#### Modular Amplifiers

The model C1501 and model C1502 are modular amplifiers designed for communications applications such as SATCOM terminals and terrestrial radios.



Both models span the 11 to 15 GHz band. The model C1501 offers a minimum gain of 10 dB while the C1502 offers 20 dB gain. Both models offer a typical power output (P1dB) at +11 dBm and typical noise figure of 4 dB. These amplifiers operate from 5 V DC. The C1501

amplifiers operate from 5 V DC. The C1501 draws a typical 80 mA and the C1502 will draw 150 mA. Price: C1501 – \$275.00 and C1502 – \$350.00 (100). Delivery: stock to eight weeks.

EPX Microwave Inc.,

San Carlos, CA (408) 313-4913, www.epxmicrowave.com.

RS No. 236

#### ■ Solid-state Power Amplifier

The S51000 C-band series of solid-state power amplifier modules range from 12 to 200 W of output power. This series features good performance, reliability and cost effectiveness in a slim and compact package. *Locus Microwave Inc.*,

State College, PA (814) 861-3200, www.locusmicrowave.com.

RS No. 238

#### Come Join a Growing Company

Hittite Microwave Corporation is an innovative designer and manufacturer of high performance analog and mixed-signal ICs, MIC modules and subsystems for RF, microwave and millimeterwave applications covering DC to 110 GHz. Our RFIC/MMIC products are developed using state-of-the-art GaAs, InGaP/GaAs, InP, SOI and SiGe semiconductor processes and support a wide variety of wireless/wired communications and sensor applications for Automotive, Broadband, Cellular Infrastructure, Fiber Optics, Microwave & Millimeterwave Communications, Military, Space and Test & Measurement markets.

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#### New Products

#### Low Noise Amplifier

The model HMC374 is a surface-mount PHEMT MMIC low noise amplifier (LNA) for



fixed wireless, CATV, microwave radio and cellular/3G base station and repeater applications from 0.3 to 3 GHz. This high dynamic range PHEMT

MMIC LNA delivers 1.5 dB noise figure, +37 dBm output IP3 and 15 dB small-signal gain at 900 MHz. The +23 dBm saturated output power and the high output intercept point makes the HMC374 also suited for driving the RF port of a high IP3 mixer, and for transmitter pre-driver applications.

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

RS No. 237

#### ■ E-band Modules

The model SCM-74056020-01 and model SCM-84056020-01 are engineering prototype



modules developed for E-band communication link system demonstration. These two mod-

ules form a complete link to cover the entire 71 to 76 GHz and 81 to 86 GHz frequency spectrum. The modules implement a high stability free running DRO, active frequency multiplier, bandpass filter, power divider, sub-harmonically pumped mixer and upconverter, low noise amplifier and power amplifier and T/R diplexer. Size: 7" × 11" × 2.5".

WiseWave Technologies Inc., Torrance, CA (310) 539-8882, www.wisewave-inc.com.

RS No. 241

#### **DEVICE**

#### ■ PIN Diode

The model MA4PBL027 is an HMIC silicon beam lead PIN diode designed for a variety of



wideband and broadband switching applications. The MA4PBL027 diode is fabricated on epitaxial wafers, which are designed to provide highly repeatable electrical charac-

teristics and low parasitics. This diode is fully passivated with silicon dioxide, silicon nitride and a BCB protective polymer. The MA4PBL027 offers low C<sub>t</sub> (30 fF), respectable R<sub>s</sub> (2.8 V) and small L<sub>s</sub> (0.3 nH). Price: \$3.75 (10,000).

M/A-COM Inc., Lowell, MA (800) 366-2266, www.macom.com.

RS No. 242

#### **SOFTWARE**

#### Extraction Tool



The Q3D Extractor<sup>TM</sup> v7 is the most recent release of the 3D quasi-static electromagnetic parasitic extraction tool. The Q3D Extractor computes 3D RLC/2D RLCG parameters from interconnect structures and automatically generates an equivalent SPICE circuit. This release introduces new features that make it easier and more reliable for engineers to import 3D CAD models and integrated circuit, printed circuit board and package layouts from third-party tools. A new fault-tolerant meshing algorithm has been added to make the meshing process tolerant to anomalies that occur in geometric data from CAD/EDA software programs. The new release also provides automatic and interactive model healing techniques that allow users to detect and repair errors in imported geometry.

Ansoft Corp., Pittsburgh, PA (412) 261-3200, www.ansoft.com.

RS No. 244

#### **SOURCES**

#### Amplified Noise Source



The model NW6G-M is an amplified noise source that features broadband frequency coverage from 10 MHz to 6 GHz. This model is ideal for wireless test applications and covers all major wireless applications. The NW6G-M also features a power out of 0 dBm, flatness of  $\pm 2$  dB, internal regulation, operates with  $\pm 15$  VDC and draws 200 mA. Size:  $\pm 10$  ×  $\pm 10$  ×

NoiseWave Corp., East Hanover, NJ (973) 386-1119, www.noisewave.com.

RS No. 245

#### ■ Militarized Rubidium Oscillator

The model 8130A is an off-the-shelf militarized rubidium oscillator that provides good



overall performance for numerous tactical applications, and excels particularly for systems requiring good phase noise under vibration. The

circuit boards of the 8130A are conformal-coated for moisture resistance, and special precautions are taken for improved shock vibration hardening. Key features include: a modern militarized design, 5 and 10 MHz sinewave outputs, a ruggedized high performance  $R_{\rm b}$  physics package and an internal temperature compensation option. Price:  $\$11,\!500$  USD.

Symmetricom Inc., San Jose, CA (978) 927-8220, www.symmttm.com.

RS No. 246

#### ■ Voltage-controlled Oscillator

The model V139ME01 is a voltage-controlled oscillator designed for the specialized mobile



radio market in the VHF band. This oscillator covers 118 to 160 MHz within 1 to 16 VDC, which greatly reduces the tuning sensitivity. This model

exhibits good single-sideband spectral purity of -115 dBc/Hz, typically, at 10 kHz from the carrier and is ready for any outdoor application as it is specified to operate over the temperature range of  $-35^{\circ}$  to  $85^{\circ}$ C. Size:  $0.50'' \times 0.50'' \times 0.13''$ . Delivery: stock to four weeks.

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

RS No. 247

#### SUBSYSTEM

#### **■** Frequency Translator

The model T8P-68N-5 is a digitally controlled PIN diode frequency translator that operates



from 6 to 18 GHz. This frequency translator offers 25 dB carrier suppression and 20 dB sideband suppression at a 500 kHz translation rate with 3 dB amplitude variate variate variate variate with 3 dB amplitude variates.

tion across the entire band. With less than 12 dB insertion loss and 1.9 VSWR, this frequency translator can handle +15 dBm CW, 1 W maximum RF input power. Size:  $3" \times 3" \times 1"$ .

G.T. Microwave Inc., Randolph, NJ (973) 361-5700, www.gtmicrowave.com.

RS No. 248

#### **SYSTEM**

#### Multicoupler Switch System

This multicoupler switch system is designed to operate in the frequency range of 0.1 to 3000



MHz in three bands, having as many at 12 inputs and eight or more outputs. Any input can be switched to any

or all of the outputs as selected by the host controller through an RS-232 or an RS-422 in-

terface. The unit has an overall gain of  $0 \pm 3 \text{ dB}$  and provides good output-to-output and output-to-input isolation. The unit's high dynamic range provides optimum performance over a wide range of input signal levels.

Mu-Del Electronics Inc., Manassas, VA (703) 368-8900, www.mu-del.com.

RS No. 249

#### **TEST EQUIPMENT**

#### WLAN Test Set



The MT8860B Wireless LAN test set is designed for radio layer measurements on all 802.11b/g devices. This integrated test set simulates a WLAN Access Point for testing devices under normal operating conditions, eliminating the need for special test mode software. When integrated into a production test system, the MT8860B measures all the key radio parameters including transmitter power, spectral mask and EVM as well as receiver sensitivity. A single test connection is all that is required to perform all measurements, which significantly reduces test times.

Anritsu Ltd., Luton, Bedfordshire, UK +44 (0)1582 433 433, www.anritsu.com.

RS No. 251

#### ■ Transient Generator System

This TGAR transient generator system is capable of generating custom pulses and can handle



a large percentage of existing specs. The complete TGAR system (consisting of the TG6083BU. T G 6 0 8 3 P S TG6083AS and TG6000LD) meets the requirements of ĹSO 7637-2 (2004) and SAE I1113-11. Features include: base current rat-

ing of 83 amps that covers 95 percent of DUT requirements, built-in oscilloscope that allows for easy pulse verification and self-calibration, pulse verification data is included in the DUT test report and LabView-based software, and built-in arbitrary waveform generators allow users to create custom waveforms.

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

RS No. 252

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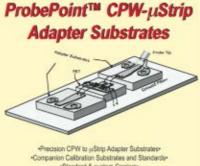
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RS 66

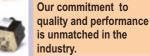


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and triple-play services and infrastructures; photonic testing of next generation optical devices, digital microwave solutions for high speed communication buses; and backplane and multiservices test solutions for next generation triple-play devices.

Agilent Technologies Inc., Palo Alto, CA (800) 829-4444, www.agilent.com.

RS No. 200

#### ELECTRO-MECHANICAL SWITCH CATALOG

This catalog presents the company's complete line of electromechanical switches with many options to suit any application from DC to 26.5 GHz. Models include sin-



gle-pole, double-throw; double-pole, threethrow; single-pole, multi-throw; and transfer switches. Options include a wide variety of connectors and actuator voltages.

EPX Microwave Inc., Burlingame, CA (408) 313-4913, www.epxmicrowave.com.

RS No. 201

#### TERMINOLOGY Guide

"Speaking RF: Wireless Communication Terminology" is a 32-page guide that defines a variety of technical terms and decodes the many acronyms in the RF and wireless industry. Several useful tables are



featured in the guide, including a quick Watts vs. dBm Conversion table and a Return Loss vs. VSWR table.

Keithley Instruments Inc., Cleveland, OH (440) 248-0400, www.keithley.com.

RS No. 202

#### NEW LITERATURE

## POWER AMPLIFIERS DATA SHEET

This data sheet provides complete detail on the company's 80 to 125 W Kuband power amplifiers, the MPC8-1220 series. 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. 203

# CABLE, CONNECTORS AND ASSEMBLY BROCHURE

This brochure features the company's ruggedized and flexible low loss SFT® coaxial cable assemblies that are ideal for interconnect applications rang-



ing from inside LRUs to demanding military or commercial systems. The broad range of available connectors covers a multitude of interface types and frequency ranges.

Times Microwave Systems, Wallingford, CT (203) 949-8424, www.timesmicrowave.com.

RS No. 204

#### TECHNICAL GUIDE

This brochure, titled "Seven Technical Reasons to Specify Bulk Metal Foil," highlights the features and benefits of ultrahigh precision bulk metal foil resistors. The updated brochure includes a



new specification for power coefficients of resistance. It also describes a new alloy that improves the existing low temperature coefficient of resistance to almost zero.

Vishay Intertechnology Inc., Malvern, PA (402) 563-6866, www.vishay.com.

RS No. 205

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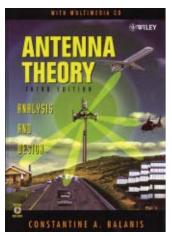
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This book's main objective is to introduce, in a unified manner, the fundamental principles of antenna theory and to apply them to the analysis, design and measurements of antennas. It is designed to meet the needs of electrical engineering and physics students at the senior undergraduate and beginning graduate levels, and those of practicing engineers. The third edition has maintained all of the features of the first two editions, including the three-dimensional graphs to display the radiation characteristics of antennas, especially the amplitude patterns. Many new features have been added to this edition:

- A new chapter on smart antennas, which is presently a hot topic of current interest to antenna engineers in a number of application areas, especially wireless communications
- cations.

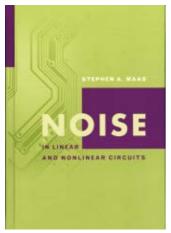
   A fractal antenna section, which introduces a new class of antennas that has re-

ceived a lot of interest and attention after the second edition was published.

- New end-of-chapter tables that provide a summary of important equations in each of the respective chapters.
- Additional new figures, photos and tables to illustrate the concepts.
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#### Noise in Linear and Nonlinear Circuits



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Stephen A. Maas Artech House • 289 pages; \$89, £55 ISBN: 1-58053-849-5

he theory of linear circuits has existed for some time but has never been collected into a comprehensive book. Nonlinear noise theory, similarly, has not been well covered in technical books. Collecting this information in one place, and explaining it in a straightforward manner, will be valuable to many people who must deal with these matters daily. This book addresses both broad theoretical and specific technical aspects of noise theory and circuit optimization. It will help professionals to optimize real world circuit performance and show how noise in both linear and nonlinear circuits can be analyzed and minimized. Chapter 1 introduces the concept of noise in communication systems, phase and amplitude noise, linear and nonlinear noise, noise analysis and circuit optimization. Chapter 2 is dedicated to noise and random processes, narrow band random processes, physical sources of noise and cyclostationary

noise. Chapter 3 covers noise figure, noise temperature and the system noise model, mixer noise and noise measurement. Noise models of solid-state devices, such as lossy elements, Schottky barrier diodes, JFEŤ and MOSFET, MESFET and HEMT, BIPOLAR and HBT, are described in Chapter 4. The noise theory of linear circuits is the subject of Chapter 5, while the noise theory of nonlinear circuits is treated in Chapter 6. Low noise amplifiers are an obviously important subject and are covered in some detail in Chapter 7. Chapter 8 explains the classical approaches to oscillator theory, nonlinear analysis of oscillators, noise in oscillators and optimization of low noise oscillators. Chapter 9 considers mixers and frequency multipliers, including essential mixer theory, noise in diode mixers, noise in FET resistive mixers, noise in active mixers, system considerations, and diode and active frequency multipliers.

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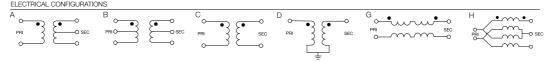
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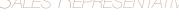


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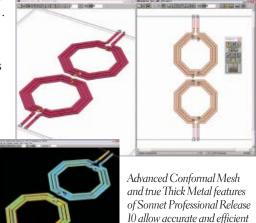
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