THE HIGH SPEED ELECTRONICS GROUP

Microwaves & RF

News
Celebrating 50 years of Weinschel

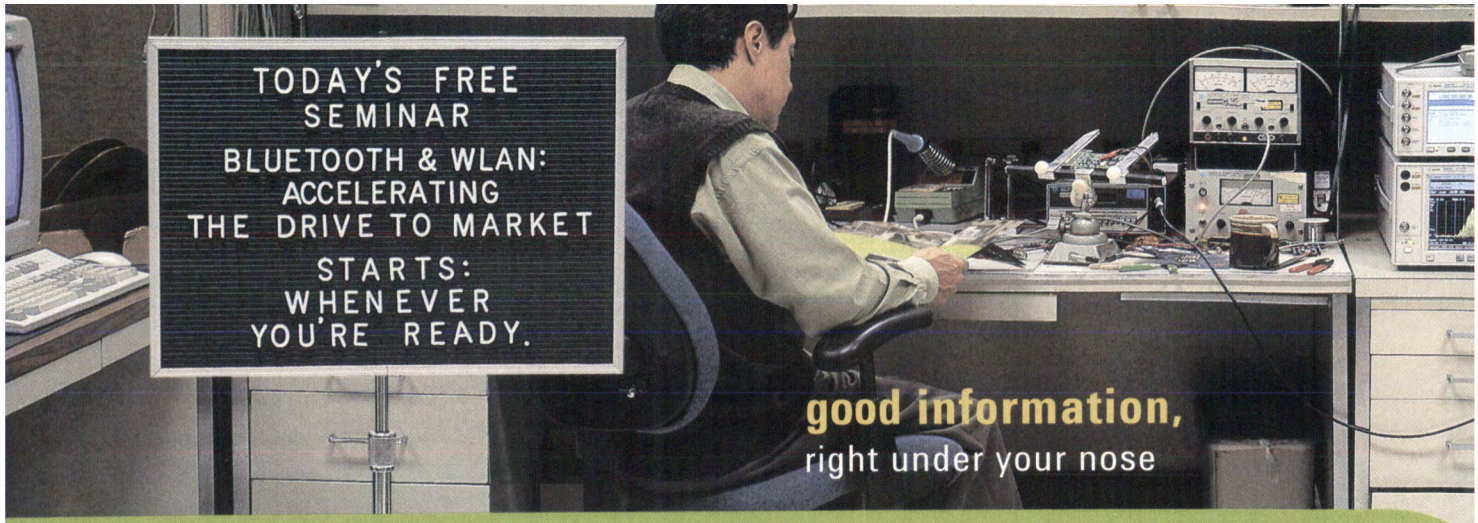
Design Feature
Select crystals for stable oscillators

Product Technology
Broadband amps drive OC-768 modulators

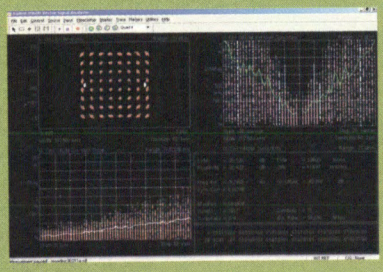
DACs Deliver Multiple Carriers



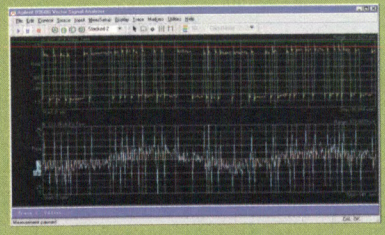
Amplifiers & Oscillators Issue



good information,
right under your nose



For this IEEE 802.11a signal, the overall EVM measurement is acceptable but viewing EVM versus time (lower left) and channel (upper right) shows the effect of a timing error.



The FSK error display can highlight the effects of unwanted frequency modulation, which may indicate the presence of spurious signals in the modulator.

The original idea was simple: use wireless links to give the wired generation more mobility. Of course, turning *Bluetooth* and Wi-Fi into reality—without much time for analysis—has been anything but simple. Perhaps we can help.

Enhancing interoperability. Many people attribute Wi-Fi's popularity to WECA testing that certifies device interoperability. Those who've passed tell us the roots of success often reach back to early tweaks in their transmitter or receiver designs. For transmitters, error vector magnitude (EVM) versus time or channel is a measure of modulation quality that can highlight underlying problems such as nonlinear distortion, phase noise and spurious signals. Conversely, making receivers more forgiving of nonideal transmitters can come from testing with impaired signals—in hardware, simulation or a system that links both.

Achieving certification. The Agilent Interoperability Certification Labs and Agilent's network of test partners are ready to help, too: they've tested hundreds of Wi-Fi devices and can help you clear the qualification hurdle.

To learn more, please visit www.agilent.com/find/wn, where you can request a FREE CD-ROM packed with articles, solution guides, and application notes such as "RF Testing of Wireless LAN Products" and "Verifying *Bluetooth* Baseband Signals."

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*0,82 FF HT les 45 seconden en journee. **DM 0,24/min ©2002 Agilent Technologies ADEP3471201/MRF *Bluetooth and the Bluetooth logos are trademarks owned by Bluetooth SIG, Inc., USA, and licensed to Agilent Technologies, Inc.*

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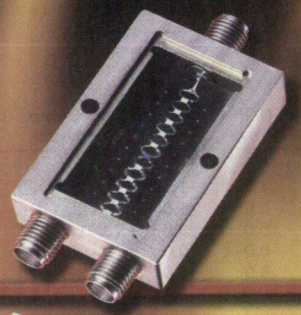

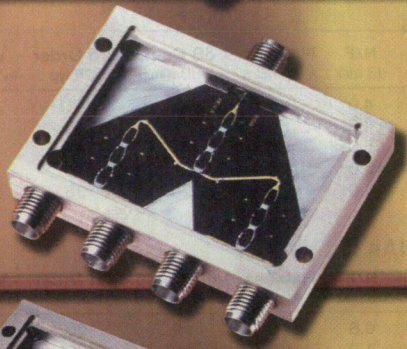

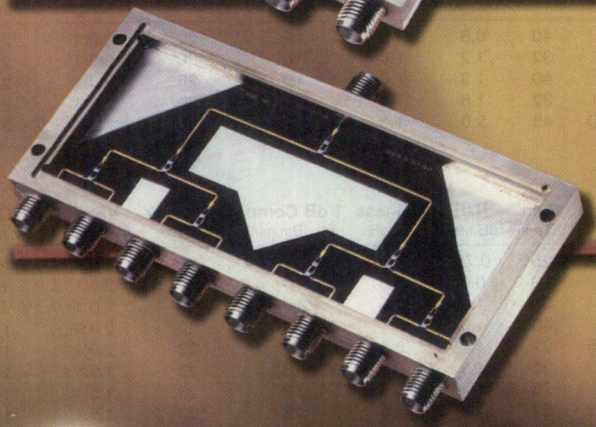

RF INPUT PARAMETERS	UNITS	MINIMUM	MAXIMUM
2 Way Power Divider - Model D0289			
RF frequency range	GHz	18	40
Insertion loss	dB		1.5
Isolation	dB	17	
Input VSWR	Ratio		1.8
Output VSWR	Ratio		1.7
Phase unbalance	Degrees		±5.0
Amplitude balance	dB		±0.5
4 Way Power Divider - Model D0489			
RF frequency range	GHz	18	40
Insertion loss	dB		2.5
Isolation	dB	17	
Input VSWR	Ratio		1.8
Output VSWR	Ratio		1.7
Phase unbalance	Degrees		±5.0
Amplitude balance	dB		±0.5
8 Way Power Divider - Model D0889			
RF frequency range	GHz	18	40
Insertion loss	dB		3.5
Isolation	dB	17	
Input VSWR	Ratio		1.8
Output VSWR	Ratio		1.7
Phase unbalance	Degrees		±5.0
Amplitude balance	dB		±0.5

For further information, please contact
John Pierro (631) 439-9137 or e-mail
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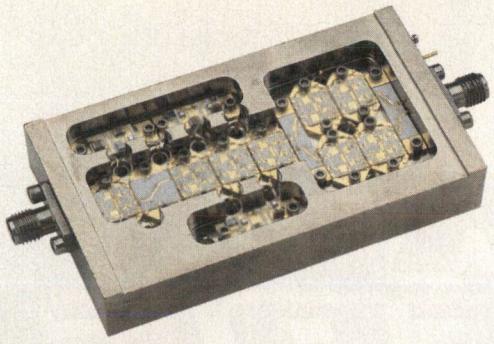

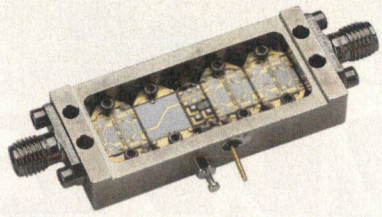

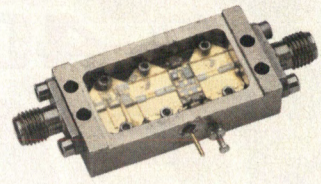

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Ultra broadband

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA018-203	0.5–18.0	20	5.0	2.5	7	17	2.0:1	250
JCA018-204	0.5–18.0	25	4.0	2.5	10	20	2.0:1	300
JCA218-506	2.0–18.0	35	5.0	2.5	15	25	2.0:1	400
JCA218-507	2.0–18.0	35	5.0	2.5	18	28	2.0:1	450
JCA218-407	2.0–18.0	30	5.0	2.5	21	31	2.0:1	500

Multi-octave amplifiers

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA04-403	0.5–4.0	27	5.0	1.5	17	27	2.0:1	550
JCA08-417	0.5–8.0	32	4.5	1.5	17	27	2.0:1	550
JCA28-305	2.0–8.0	22	5.0	1.0	20	30	2.0:1	550
JCA212-603	2.0–12.0	32	5.0	3.0	14	24	2.0:1	550
JCA618-406	6.0–18.0	20	6.0	2.0	25	35	2.0:1	600
JCA618-507	6.0–18.0	25	6.0	2.0	27	37	2.0:1	800

Medium-power amplifiers

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-P01	1.35–1.85	35	4.0	1.0	33	41	2.0:1	1000
JCA34-P02	3.1–3.5	40	4.5	1.0	37	45	2.0:1	2200
JCA56-P01	5.9–6.4	30	5.0	1.0	34	42	2.0:1	1200
JCA812-P03	8.0–12.0	40	5.0	1.5	33	40	2.0:1	1700
JCA1218-P02	12.0–18.0	22	4.0	2.0	25	35	2.0:1	700

Low-noise octaveband LNAs

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-3001	1.0–2.0	40	0.8	1.0	10	20	2.0:1	200
JCA24-3001	2.0–4.0	32	1.2	1.0	10	20	2.0:1	200
JCA48-3001	4.0–8.0	40	1.3	1.0	10	20	2.0:1	200
JCA812-3001	8.0–12.0	32	1.8	1.0	10	20	2.0:1	200
JCA1218-800	12.0–18.0	45	2.0	1.0	10	20	2.0:1	250

Narrowband LNAs

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-1000	1.2–1.6	25	0.75	0.5	10	20	2.0:1	80
JCA23-302	2.2–2.3	30	0.8	0.5	10	20	2.0:1	80
JCA34-301	3.7–4.2	30	1.0	0.5	10	20	2.0:1	90
JCA56-401	5.4–5.9	40	1.0	0.5	10	20	2.0:1	120
JCA78-300	7.25–7.75	27	1.2	0.5	13	23	2.0:1	120
JCA910-3000	9.0–9.5	25	1.3	0.5	13	23	1.5:1	150
JCA910-3001	9.5–10.0	25	1.4	0.5	13	23	1.5:1	150
JCA1112-3000	11.7–12.2	27	1.4	0.5	13	23	1.5:1	150
JCA1213-3001	12.2–12.7	25	1.4	0.5	10	20	2.0:1	200
JCA1415-3001	14.4–15.4	35	1.6	1.0	14	24	2.0:1	200
JCA1819-3001	18.1–18.6	25	2.0	0.5	10	20	2.0:1	200
JCA2021-3001	20.2–21.2	25	2.5	0.5	10	20	2.0:1	200

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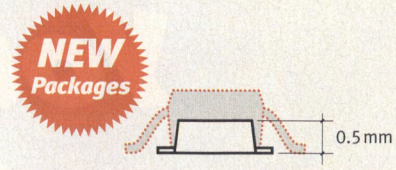


- **Flat Lead** design reduces parasitics and improves electrical performance
- **Low Profile** is ideal for VCO modules and other space-constrained designs

Oscillators & Buffer Amps

With the best *1/f* performance available, these devices help you achieve the phase noise your design demands. They're also available in Twin Transistors.

Part Number	Corner Freq*	V_{CE}	I_C	Package
NE851M13	1 KHz	1 V	5 mA	**M13**
NE894M13	3 KHz	1 V	5 mA	**M13**
NE685M13	5 KHz	3 V	5 mA	**M13**

**Review Application Note AN1026 on our website for more information on 1/f noise characteristics and corner frequency calculation.*

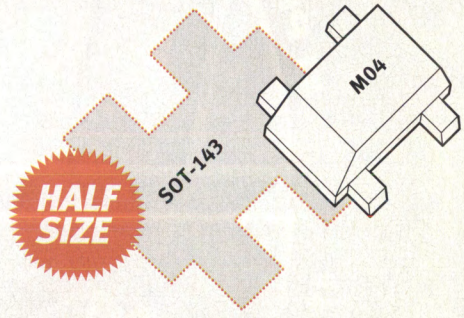


M13 One sixth the footprint a SOT-323

LNAs

Need low noise and high gain in an ultraminiature package for your hand-held wireless products? These new high frequency NPN transistors deliver!

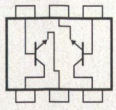
Part Number	Description	NF	Gain	Freq	Package
NESG2030M04	35 GHz f_T LNA	0.9 dB	16 dB	2 GHz	**M04**
NE662M04	23 GHz f_T LNA	1.1 dB	16 dB	2 GHz	**M04**
NE687M13	14 GHz f_T LNA	1.4 dB	14 dB	1 GHz	**M13**



M04 Half the footprint of a SOT-143

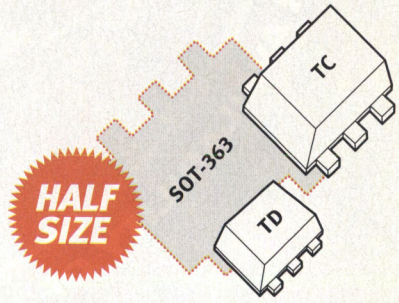
Twin Transistor Devices

Cascode LNAs, cascade LNAs and oscillator/buffer combinations are just three possible uses of these versatile devices. *Matched Die* versions pair two adjacent die from the wafer to help simplify your design, while *Mixed Die* versions — an NEC exclusive — let you optimize oscillator performance while achieving the buffer amp output power you need. Many combinations are available.



One of three pin-outs available

Part Number	Description	Q1 Spec	Q2 Spec
UPA802TC	Matched Die/Cascade LNA	NE681	NE681
UPA826TC	Matched Die/Osc-Buffer Amp	NE685	NE685
UPA861TD	Mixed Die/Osc-Buffer Amp	NE687	NE894
UPA862TD	Mixed Die/Osc-Buffer Amp	NE685	NE851



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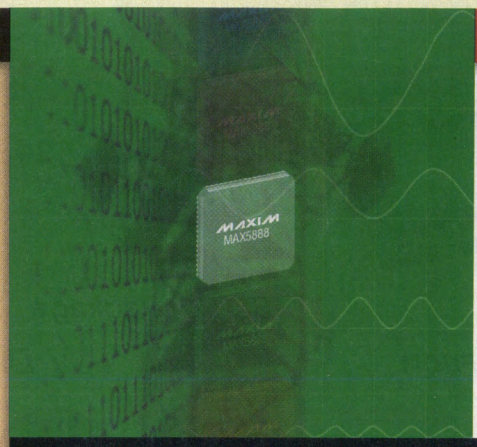

COVER STORY

95 **DACs Deliver Multiple Carriers**

This family of high-resolution, high-speed DACs provides the performance levels needed for DDS sources and generation of multicarrier signals in next-generation cellular base stations.

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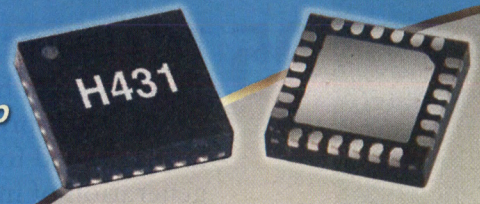

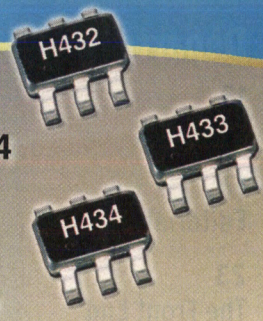

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HMC431LP4	5.5 - 6.1	-102 dBc/Hz	+2	$7.00
HMC358MS8G	5.8 - 6.8	-110 dBc/Hz (at C-band)	+11	$5.63
HMC401QS16G	13.2 - 13.5	-105 dBc/Hz (at Ku-band)	-7	CALL
HMC398QS16G	14.0 - 15.0	-110 dBc/Hz (at Ku-band)	+6.0	CALL

Standard Product Plastic SMT Dividers*

Part Number	Freq. (GHz)	Divide Ratio	Phase Noise @ 100K Offset	USD @ 10K PCS
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HMC364S8G	DC - 12.5	2	-145 dBc/Hz	$5.25
HMC437MS8G	DC - 8.0	3	-148 dBc.Hz	$8.94
HMC433	DC - 8.0	4	-150 dBc/Hz	$2.48
HMC365S8G	DC - 13.0	4	-151 dBc/Hz	$5.25
HMC438MS8	DC - 8.0	5	-150 dBc.Hz	$8.94
HMC434	DC - 8.0	8	-150 dBc/Hz	$2.77
HMC363S8G	DC - 12.0	8	-153 dBc/Hz	$5.25

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ACTUAL SIZE

SOT26 9mm² MS8 14.8mm² S8 29.4mm² QS16 29.4mm² LP4 16mm²



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RF Peak Power Meter Selection Meeting

Requirements:

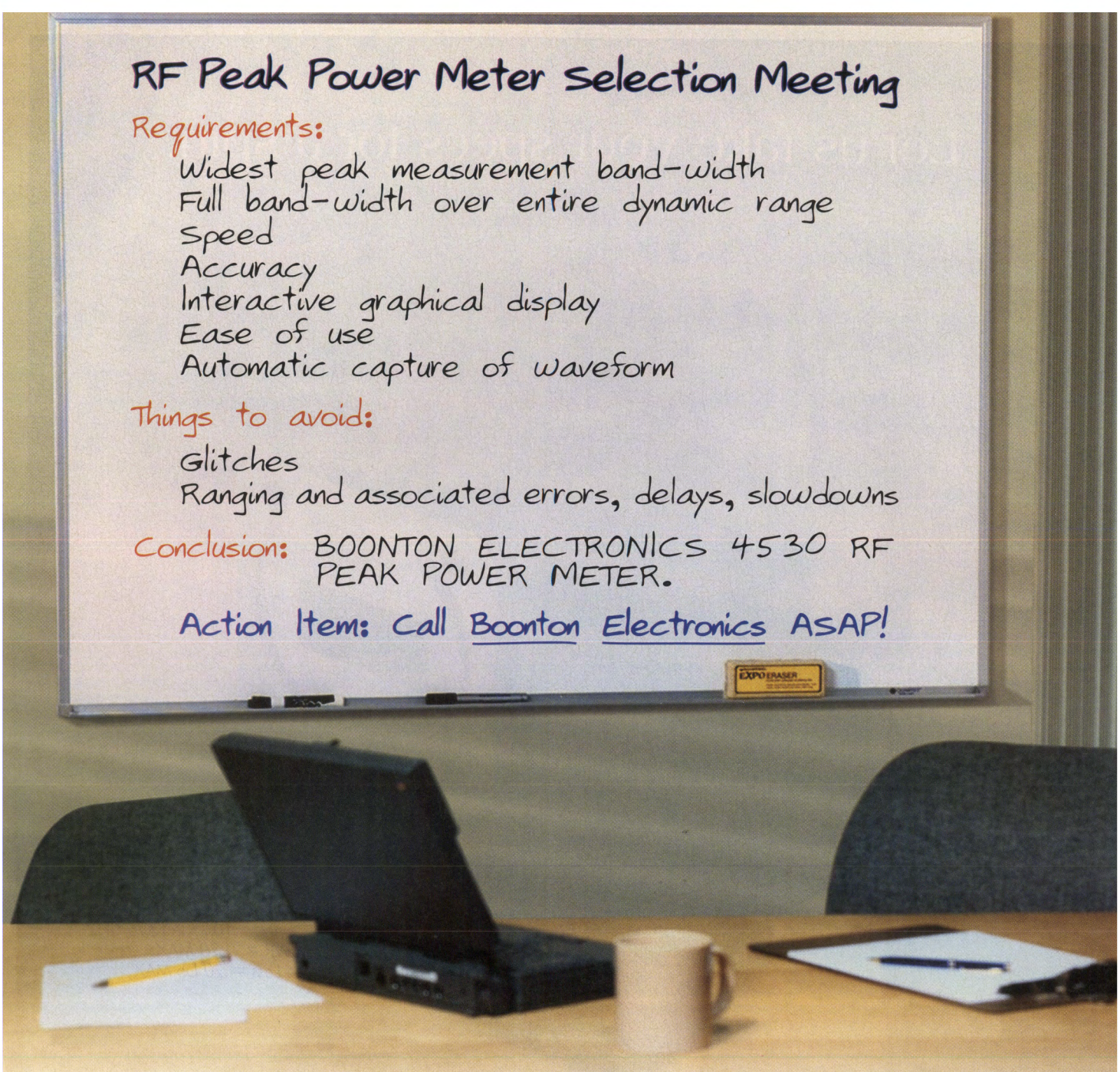
Widest peak measurement band-width
Full band-width over entire dynamic range
Speed
Accuracy
Interactive graphical display
Ease of use
Automatic capture of waveform

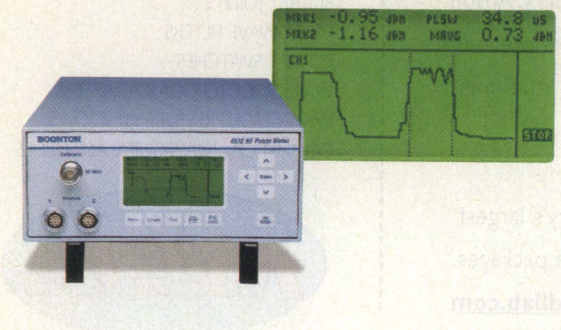
Things to avoid:

Glitches
Ranging and associated errors, delays, slowdowns

Conclusion: BOONTON ELECTRONICS 4530 RF PEAK POWER METER.

Action Item: Call Boonton Electronics ASAP!





The Boonton 4530 RF Peak Power Meter brings peak power measurement capabilities to both the laboratory and production, making Peak, CW Power and RF Voltage measurements at high speed from 10 Hz to 40 GHz.

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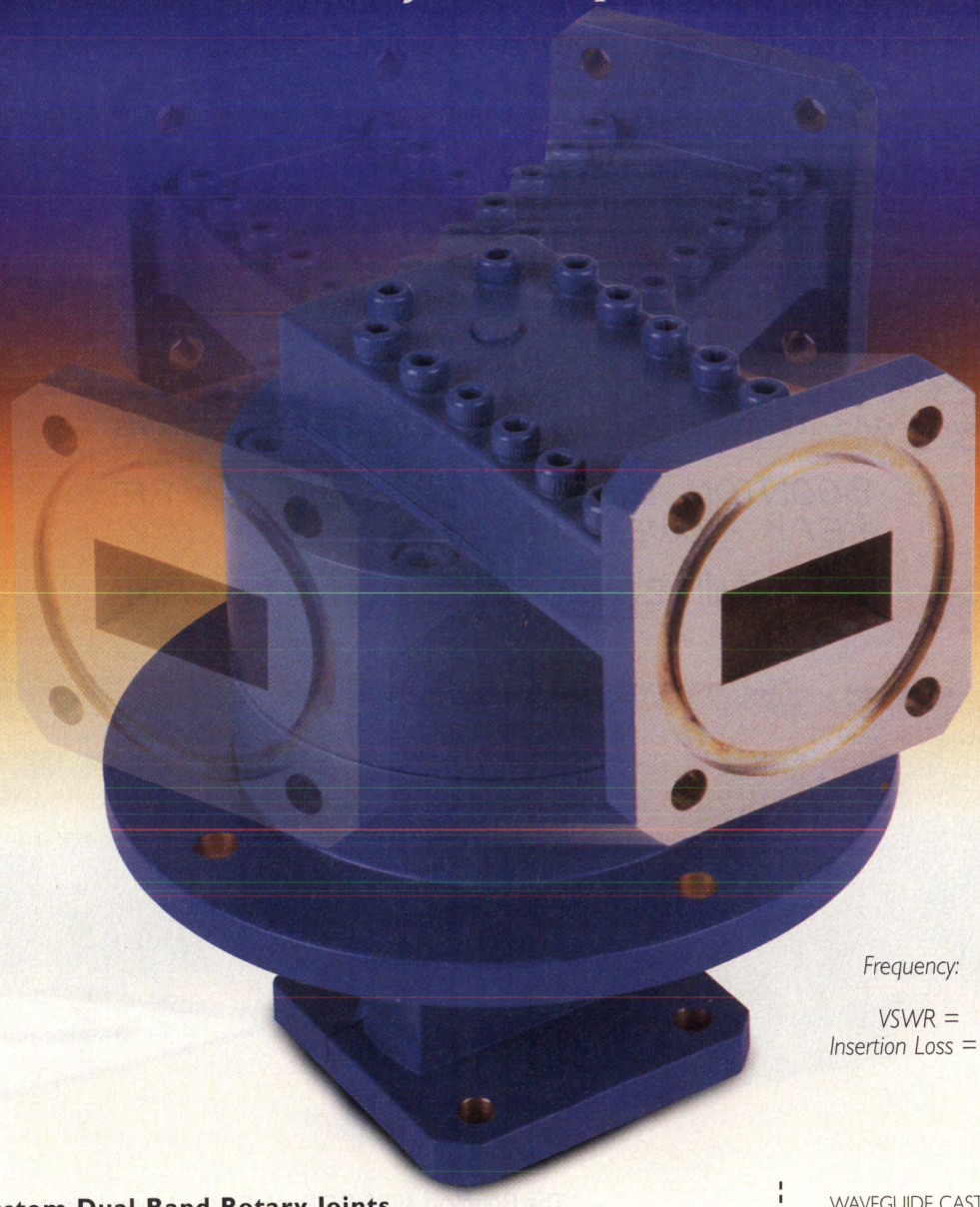

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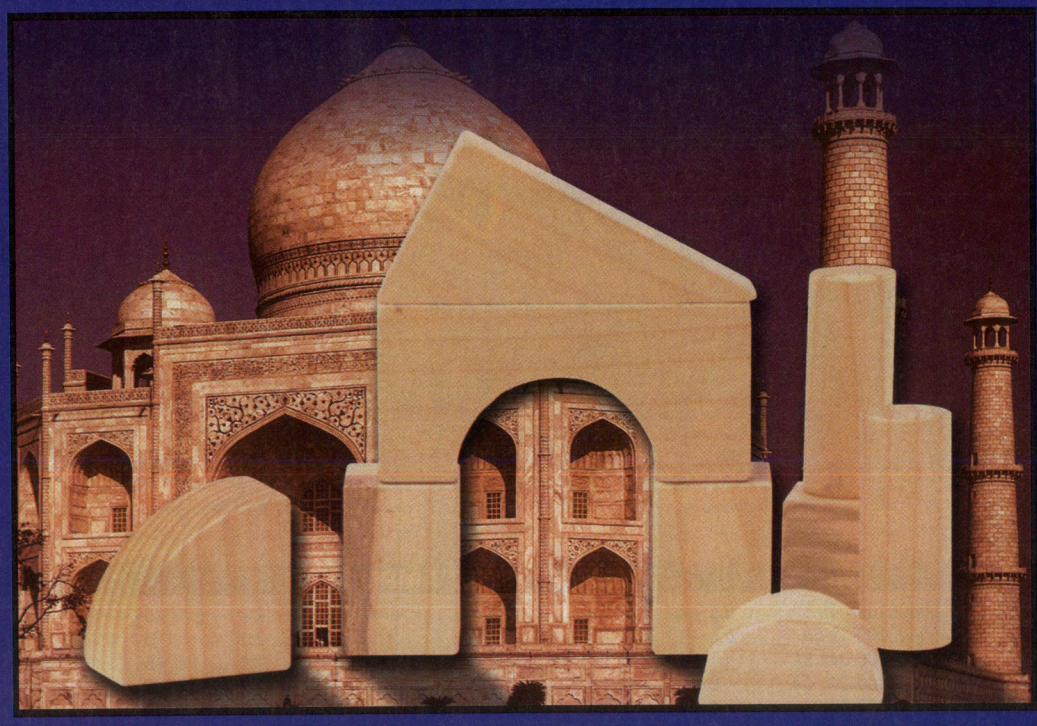

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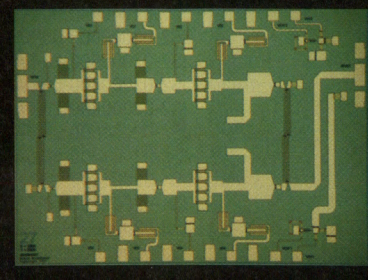

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Ultra-Low Noise AMPLIFIERS

VHF To V-BAND

MODEL NUMBER	FREQUENCY RANGE (GHz)	GAIN (dB, Min.)	GAIN VARIATION (±dB, Max.)	NOISE FIGURE (dB, Max.)	VSWR IN	VSWR OUT	POWER OUT @ 1 dB COMP. (dBm, Min.)	DC POWER @ +15 V (mA, Nom.)
OCTAVE BAND AMPLIFIERS								
JS2-00500100-045-5A	0.5 – 1	35	1	0.45	2:1	2:1	5	250
JS2-00500100-12-5A	0.5 – 1	35	1.2	1	2:1	2:1	5	250
JS2-01000200-045-5A	1 – 2	33	1	0.45	2:1	2:1	5	250
JS2-02000400-045-5A	2 – 4	28	1.2	0.45	2:1	2:1	5	175
JS2-04000800-08-0A	4 – 8	22	1.2	0.8	2:1	2:1	0	150
JS3-04000800-08-5A	4 – 8	30	1	0.8	2:1	2:1	5	175
JS3-04000800-15-5A	4 – 8	30	1	1.5	2:1	2:1	5	175
JS2-08001200-11-5A	8 – 12	15	1	1.1	2:1	2:1	5	150
JS3-08001200-11-5A	8 – 12	25	1	1.1	2:1	2:1	5	175
JS3-08001200-15-5A	8 – 12	25	1	1.5	2:1	2:1	5	175
JS3-12001800-16-5A	12 – 18	23	1	1.6	2:1	2:1	5	175
JS4-12001800-145-5A	12 – 18	30	1	1.45	2:1	2:1	5	200
JS4-12001800-30-5A	12 – 18	30	1	3	2:1	2:1	5	200
JS2-18002600-20-5A	18 – 26	14	2	2	2.5:1	2.5:1	5	100
JS2-18002600-30-5A	18 – 26	14	2	3	2.5:1	2.5:1	5	100
JS3-18002600-20-5A	18 – 26	22	1.8	2	2.5:1	2.5:1	5	175
JS3-18002600-30-5A	18 – 26	22	1.8	3	2.5:1	2.5:1	5	175
JS4-18002600-19-5A	18 – 26	33	1.5	1.9	2:1	2:1	5	200
JS4-18002600-26-5A	18 – 26	33	1.5	2.6	2:1	2:1	5	200
JS2-26004000-35-5A	26 – 40	10	2	3.5	2.5:1	2.5:1	5	100
JS2-26004000-45-5A	26 – 40	10	2	4.5	2.5:1	2.5:1	5	100
JS3-26004000-35-5A	26 – 40	18	2.5	3.5	2.5:1	2.5:1	5	175
JS3-26004000-45-5A	26 – 40	18	2.5	4.5	2.5:1	2.5:1	5	175
JS4-26004000-40-5A	26 – 40	23	2.5	4	2:1	2:1	5	200
JS4-40006000-65-0A	40 – 60	15	3	6.5	2.75:1	2.75:1	0	175
MULTIOCTAVE BAND AMPLIFIERS								
JS2-00500200-07-5A	0.5 – 2	32	1	0.7	2:1	2:1	5	295
JS2-00500200-15-5A	0.5 – 2	32	1	1.5	2:1	2:1	5	295
JS2-01000400-08-5A	1 – 4	27	1	0.8	2:1	2:1	5	200
JS2-01000400-20-5A	1 – 4	27	1	2	2:1	2:1	5	200
JS2-02000600-08-5A	2 – 6	22	1	0.8	2:1	2:1	5	125
JS2-02000600-20-5A	2 – 6	22	1	2	2:1	2:1	5	125
JS2-02000800-08-0A	2 – 8	22	1.25	0.8	2:1	2:1	0	125
JS2-02000800-20-0A	2 – 8	18	1.25	2	2:1	2:1	0	125
JS3-02001800-25-5A	2 – 18	23	1.8	2.5	2.5:1	2.5:1	5	150
JS3-02001800-50-5A	2 – 18	23	1.8	5	2.5:1	2.5:1	5	150
JS4-02001800-22-5A	2 – 18	30	2	2.2	2.5:1	2.5:1	5	200
JS4-02001800-50-5A	2 – 18	30	2	5	2.5:1	2.5:1	5	200
JS3-02002600-33-5A	2 – 26	21	2.5	3.3	2.5:1	2.5:1	5	150
JS3-02002600-40-5A	2 – 26	21	2.5	4	2.5:1	2.5:1	5	150
JS3-06001800-16-5A	6 – 18	23	1.8	1.6	2:1	2:1	5	125
JS3-06001800-30-5A	6 – 18	23	1.8	3	2:1	2:1	5	125
JS4-06001800-145-5A	6 – 18	31	2	1.45	2:1	2:1	5	200
JS4-06001800-30-5A	6 – 18	31	2	3	2:1	2:1	5	200

MITEQ's JS SERIES AMPLIFIERS

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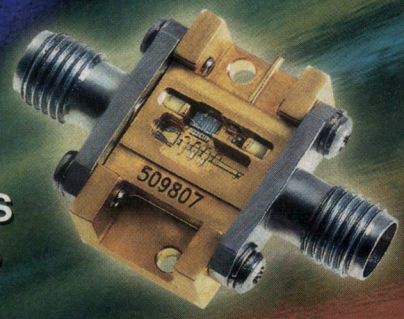
- Low Phase Distortion Design



Actual
18 to 40 GHz Design

MODEL NUMBER	FREQUENCY RANGE (GHz)	GAIN (dB, Min.)	GAIN VARIATION (±dB, Max.)	NOISE FIGURE (dB, Max.)	VSWR IN	VSWR OUT	POWER OUT @ 1 dB COMP. (dBm, Min.)	DC POWER @ +15 V (mA, Nom.)
MULTIOCTAVE BAND AMPLIFIERS (continued)								
JS3-08001800-16-5A	8 – 18	24	1.5	1.6	2:1	2:1	5	150
JS3-08001800-30-5A	8 – 18	24	1.5	3	2:1	2:1	5	150
JS4-08001800-145-5A	8 – 18	32	2	1.45	2:1	2:1	5	200
JS4-08001800-30-5A	8 – 18	32	2	3	2:1	2:1	5	200
JS3-12002600-25-5A	12 – 26	22	2.5	2.5	2.2:1	2.2:1	5	150
JS3-12002600-35-5A	12 – 26	22	2.5	3.5	2.2:1	2.2:1	5	150
JS4-12002600-22-5A	12 – 26	32	2.2	2.2	2:1	2:1	5	200
JS4-12002600-35-5A	12 – 26	32	2.2	3.5	2:1	2:1	5	200
JS3-18004000-38-5A	18 – 40	16	2.5	3.8	2.5:1	2.5:1	5	150
JS3-18004000-50-5A	18 – 40	16	2.5	5	2.5:1	2.5:1	5	150
JS4-18004000-30-5A	18 – 40	23	2.5	3	2.5:1	2.5:1	5	200
JS4-18004000-50-5A	18 – 40	23	2.5	5	2.5:1	2.5:1	5	200
ULTRAWIDE BAND AMPLIFIERS								
JS2-00100200-07-5A	0.1 – 2	32	1	0.7	2:1	2:1	5	295
JS2-00100200-15-5A	0.1 – 2	32	1	1.5	2:1	2:1	5	295
JS2-00100400-08-5A	0.1 – 4	27	1	0.8	2:1	2:1	5	200
JS2-00100400-12-5A	0.1 – 4	27	1	1.2	2:1	2:1	5	200
JS2-00100600-10-3A	0.1 – 6	23	1.5	1	2:1	2:1	3	175
JS2-00100600-20-3A	0.1 – 6	23	1.5	2	2:1	2:1	3	175
JS2-00100800-13-0A	0.1 – 8	20	1.5	1.3	2:1	2:1	0	175
JS2-00100800-25-0A	0.1 – 8	20	1.5	2.5	2:1	2:1	0	175
JS3-00101000-20-5A	0.1 – 10	23	1.5	2.0	2.5:1	2:1	5	150
JS3-00101000-35-5A	0.1 – 10	23	1.5	3.5	2.5:1	2:1	5	150
JS3-00101200-21-5A	0.1 – 12	23	1.5	2.1	2.5:1	2:1	5	150
JS3-00101200-35-5A	0.1 – 12	23	1.5	3.5	2.5:1	2:1	5	150
JS3-00101800-24-5A	0.1 – 18	23	1.8	2.4	2.5:1	2.2:1	5	150
JS3-00101800-40-5A	0.1 – 18	23	1.8	4	2.5:1	2.2:1	5	150
JS4-00101800-23-5A	0.1 – 18	29	1.8	2.3	2.5:1	2.2:1	5	200
JS4-00101800-40-5A	0.1 – 18	29	1.8	4	2.5:1	2.2:1	5	200
JS4-00102000-25-5A	0.1 – 20	28	1.8	2.5	2.5:1	2.5:1	5	200
JS4-00102000-35-5A	0.1 – 20	28	1.8	3.5	2.5:1	2.5:1	5	200
JS3-00102600-33-5A	0.1 – 26	20	2.5	3.3	2.5:1	2.5:1	5	150
JS3-00102600-42-5A	0.1 – 26	20	2.5	4.2	2.5:1	2.5:1	5	150
JS4-00102600-28-5A	0.1 – 26	27	2.5	2.8	2.5:1	2.5:1	5	200
JS4-00102600-50-5A	0.1 – 26	27	2.5	5	2.5:1	2.5:1	5	200
JS4-00104000-65-5A	0.1 – 40	14	4.5	6.5	2.75:1	2.75:1	5	200
JS4-00104000-85-5A	0.1 – 40	14	4.5	8.5	2.75:1	2.75:1	5	200

For additional information or technical support, please contact either Rosalie DeSousa at (631) 439-9458, e-mail rdesousa@miteq.com or Rizwan Syed at (631) 439-9267, e-mail rsyed@miteq.com

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Equation Corrections

▶▶THANK YOU FOR publishing my article entitled "Gauge Nonthermal Effects Of Microwave Fields" in the September issue (p. 72). I found the following mistakes in the article:
Below Eq. 1: h should be θ.
Below Eq. 2: a should be a = a property of the molecule.

Dr. A. Kumar
President
AK Electromagnetique, Inc.

Baltimore MES 2002

▶▶I WAS A LITTLE reluctant to exhibit at a regional show, especially without walking it first. But we decided that since it was a military show, and Baltimore is near of many of our military customers, it would be a good idea to exhibit. We were pleasantly surprised with the quality of the exhibitors and the amount of traffic generated from the morning technical sessions, which came to the floor after their sessions.

John Sailer
Tensolite

Editor's Note: The 2002 Military Electronics Show (MES) was held on September 24-25, 2002 at the Baltimore Convention Center in Baltimore, MD.

The "Team" Concept

▶▶THE LAST TIME that I submitted a letter to the Feedback page, I voiced my concern for the lack of mentors in the workplace. I was hopeful that readers would respond to my letter, but nothing materialized. Either everyone agrees with me, no one reads the Feedback section, or no one found the content substantive enough to write to the editor of *Microwaves & RF* to tell him their side of the story. Having been in the RF electronics industry for over 13 years now and having been "thrown in the deep end" without a mentor to guide me to some degree, I was hoping to elicit SOME response from the *Microwaves & RF* readers who might have had a similar experience. Perhaps I am naive in thinking that things are rosier elsewhere.

I ended my August letter stating that there used to be a team spirit and desire to see others and the company do well. Though this spirit and desire are not completely absent, it appears that there are many who are isolated and have very little interaction with other engineers. This may be the atmosphere of large companies. Are the conditions the same at smaller companies, where they hopefully have more clearly defined goals and products?

John David
Company name withheld

Above letter continued in Dec.—Ed.

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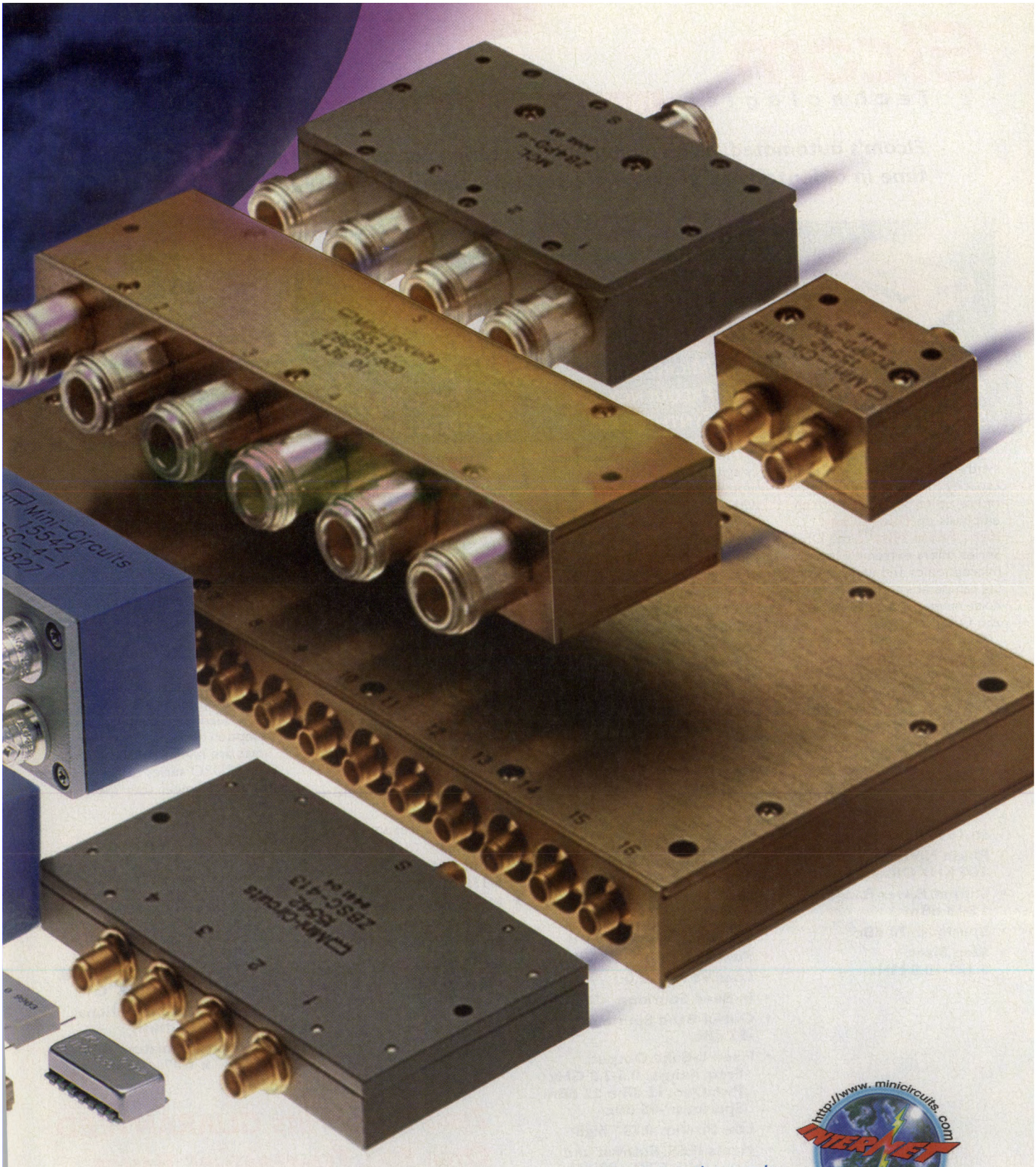

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SPECIFICATIONS

- **Frequency Range: 0.5-23 GHz**
- **Tuning Bandwidths up to 1400 MHz**
- **Phase Noise: -128 dBc at 100 KHz Offset**
- **Output Power Range: 12-18 dBm**
- **Spurious: -70 dBc**
- **Step Sizes: 0.125-10.0 MHz**



MICROWAVE FREQUENCY SYNTHESIZERS

This line of compact frequency synthesizers employs a single module design implemented with CMOS, ASIC, advanced RF MMIC and a dedicated microcomputer. A Ku-band synthesizer with 1 KHz step, 2.2 GHz bandwidth and integrated L-band LFLO consumes only 8 watts–a 65% savings compared to competing units.

Very low phase noise makes the MFS Series ideal for applications in Satcom converters (L, X, C, Ku and Ka Bands), Instrumentation and Wireless Communications.

SPECIFICATIONS

- **Output Frequency: 1-23 GHz**
- **Frequency Bandwidth: 1-2.25 GHz**
- **Phase Noise 20 dB Better than IESS**
- **Step Size: 1 KHz or 125 KHz**
- **Switching Speed: 50 ms**
- **Power Output: 12-16 dBm**
- **Load VSWR: 2.0:1**
- **In-Band Spurious: -70 dBc**
- **Out-of-Band Spurious: -82 dBc**
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  Freq. Range: 0.5-3.0 GHz
  Pwr. Out.: 12 dBm ±2 dBm
  Spurious: -95 dBc
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SPECIFICATIONS

- **Typical Frequencies: 1112.5, 1950, 3025, 5100 and 5450 MHz**
- **Output Power: +12 dBm, ±2 dBm**
- **Optional Internal Ref. Oscillator**
- **Input Reference: 5-150 MHz**
- **Meets MIL-STD-188 and IESS 308**
- **Spurious (all): < -100 dBc**
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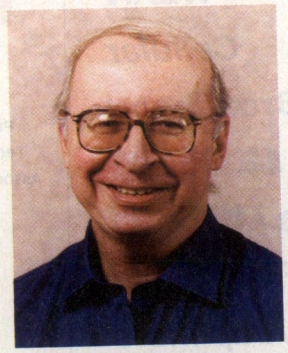
Where Did All The Wireless Go?



High-frequency electronics manufacturers may have been pondering that question these past two years, wondering what became of the wireless business. The industry is nearing the end of what has been a tumultuous two years, where it seemed that the bottom has dropped out of nearly every wireless market.

Cellular technology is finally, gradually moving into 3G, with research progressing to strategies for fourth and even fifth generations. Yet, the cellular or PCS portion of the wireless industry is no longer large enough to sustain all of the microwave companies that once relied upon it for growth. True, some device suppliers have been able to develop the right product mix to capture a generous share of the cellular hardware market—a recent visit to RF Micro Devices (Greensboro, NC) verified that company's stunning growth since 1991 is largely due to sales of chip sets to cellular markets.

The cellular or PCS portion of the wireless industry is no longer large enough to sustain all of the microwave companies that once relied upon it for growth.

Yet, the number of cellular handset suppliers is relatively small, implying that only a limited number of chip suppliers are needed to support even a large volume of handset sales. And with fierce competition among service providers forcing those companies to carefully monitor their infrastructure expenditures, opportunities have diminished in that part of the cellular market. Still, wireless is more than just cellular communications. Two "network" technologies, Bluetooth and WLANs, have survived long gestation periods and now hint at tremendous long-term growth potential. Designers of WLAN devices, systems, and software now have a collection of IEEE standards to guide them, including 802.11a, 802.11b, and 802.11g. Bluetooth also has a standard promoted by the IEEE, 802.15. And with a critical mass of more than 700 commercial Bluetooth products already on the market, it appears that Bluetooth and WLAN applications will continue to grow for the next several years.

Add to this an increasing demand for broadband Internet access, and a need for methods beyond DSL and cable modems for broadband-to-the-home or "last mile" connections, and it is easy to envision individual residences as two-way servers on a vast voice and data Internet. And wireless technology may just be the most cost-effective means of achieving such a vision.

No one can predict the future of wireless. But trends can be noted at a show such as the Wireless Systems Design Conference & Expo (www.wsdexpo.com). It might be the easiest way to track the key applications and whether any emerging technologies, such as UWB, stands to displace existing wireless standards.

Jack Browne

Publisher/Editor

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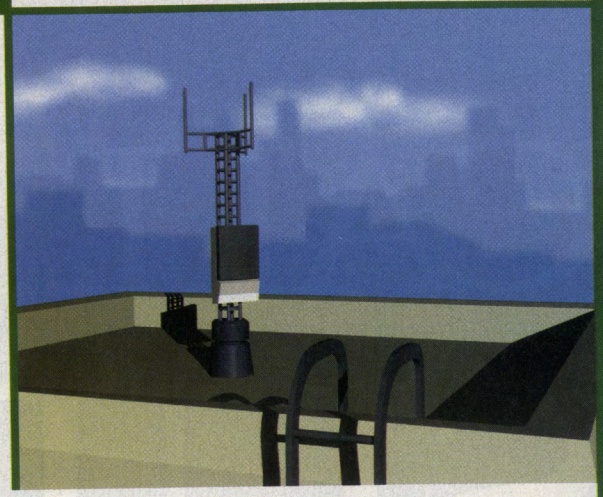

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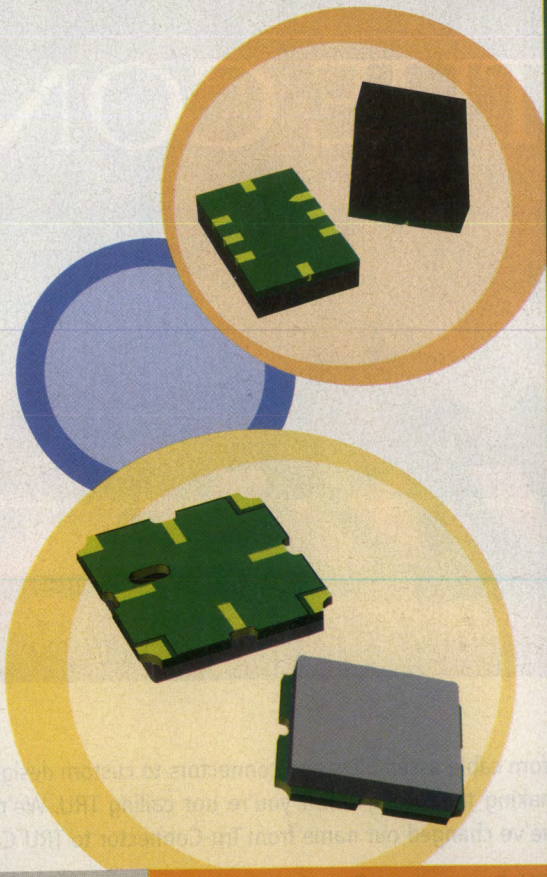

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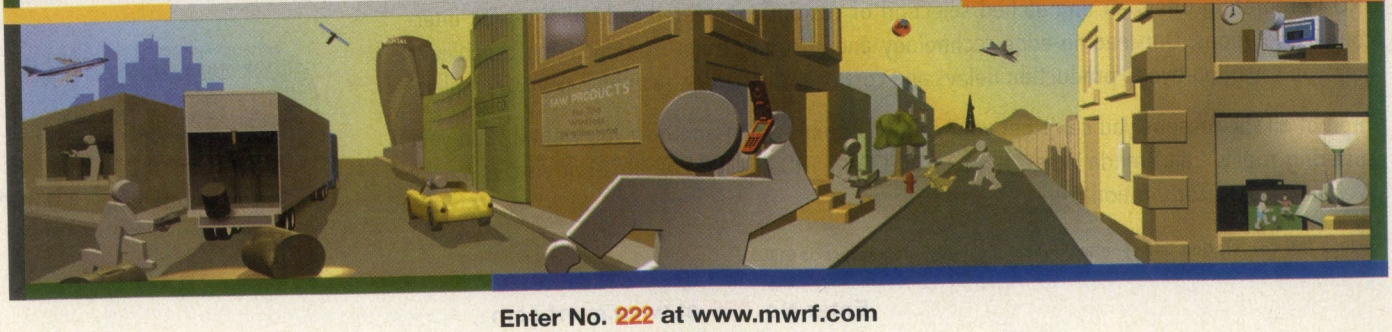

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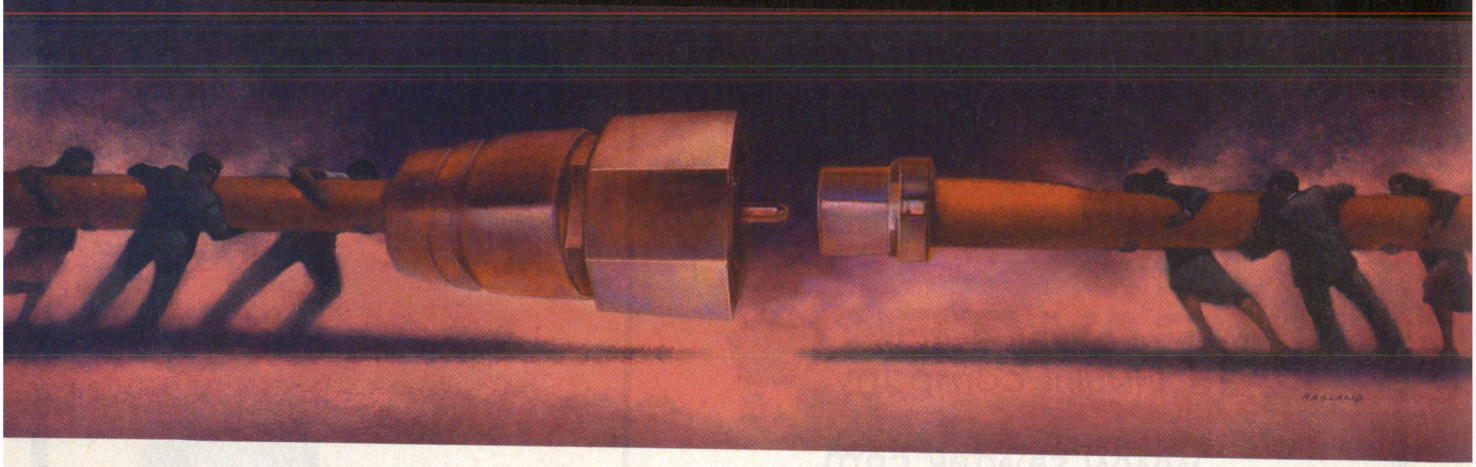

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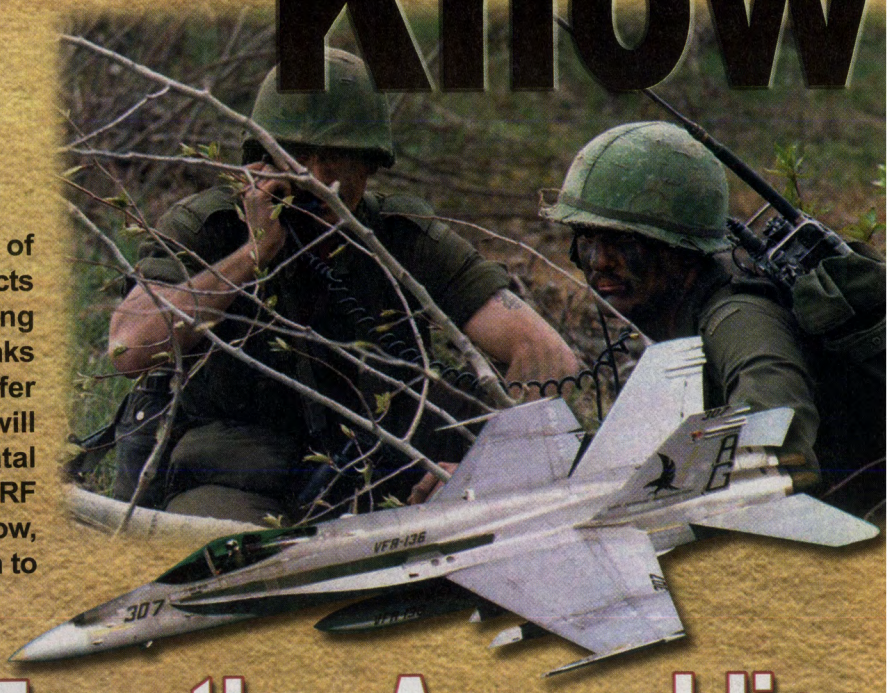

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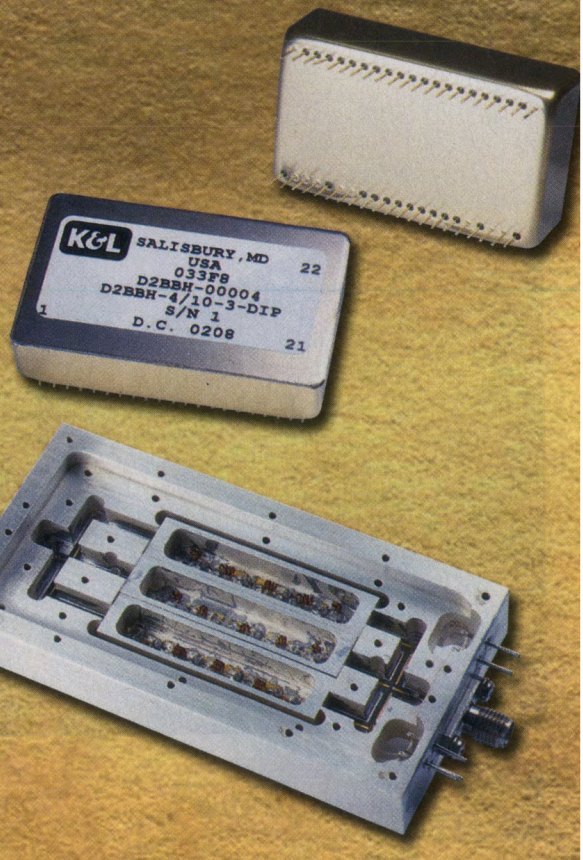

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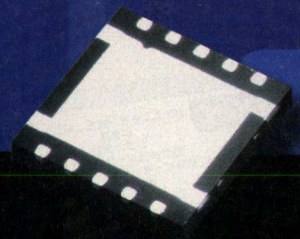

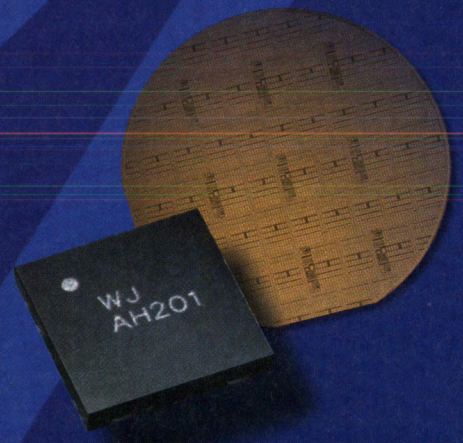

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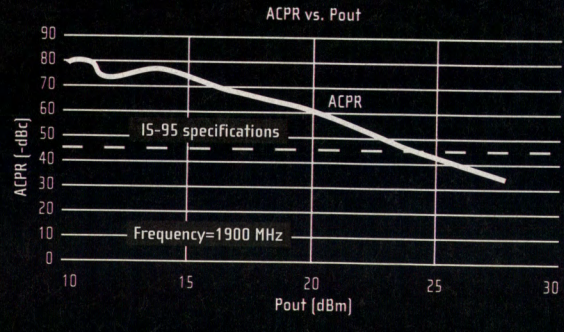

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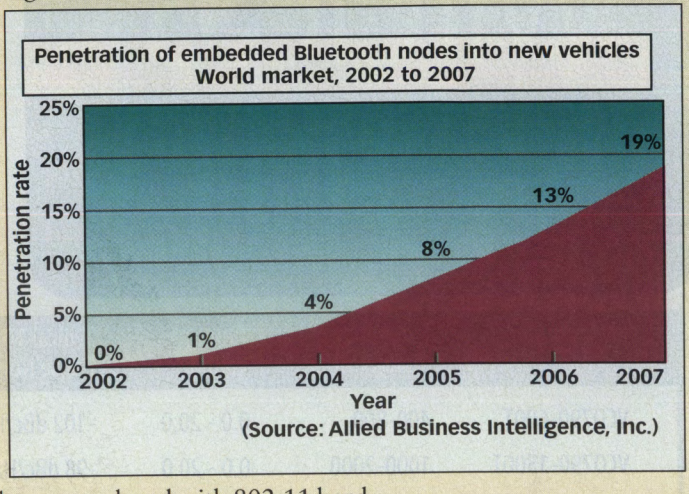
the front end

News items from the communications arena.

Bluetooth And Wi-Fi Technologies Will Revolutionize Automotive Landscape

OYSTER BAY, NY—According to the findings in "Automotive Wireless Networks: Examining The Proliferation of WLAN and PAN Technologies Into The Automotive Platform," a report from Allied Business Intelligence, Inc. (ABI), the use of Bluetooth and Wi-Fi (a.k.a. 802.11) wireless technologies in the automobile will dramatically alter the face of the automotive environment in and out of the vehicle. Future Wi-Fi and Bluetooth-based automotive applications will deliver new opportunities to all aspects of the industry, from silicon (Si) vendors and hardware manufacturers to automakers and gasoline retailers.



Chrysler's UConnect Bluetooth hands-free car kit will mark Bluetooth's introduction into a production vehicle. But while telephony may be Bluetooth's key automotive market driver, Wi-Fi's principal driver stems from the Federal Communications Commission's (FCC's) allocation of the 5.850-to-5.925-GHz band for dedicated short-range communications (DSRC).

Although it may be several years before vehicles are produced with 802.11 hardware, Bluetooth-enabled equipment will be embedded in several new American, Japanese, and European vehicles beginning in 2003. According to the report's findings, nearly 20 percent of all new vehicles will feature embedded Bluetooth hardware by 2007 **(see figure)**, while approximately 12 percent will contain embedded 802.11 hardware.

Aeroflex Is Ranked As One Of America's Fastest-Growing Firms

PLAINVIEW, NY—*Business 2.0* magazine has ranked Aeroflex, Inc., a designer, developer, and manufacturer of microelectronics and automated testing solutions for the broadband communications market, number 52 on its recent list of the 100 fastest-growing technology companies. The list appeared in *Business 2.0's* October edition. The publication's management selected Aeroflex from a list of more than 2000 publicly traded tech companies.

Zacks Investment Research compiled the list of 2000 publicly traded tech companies for *Business 2.0*, from which 5 percent qualified. The criteria used by the publication in making its selections included a combination of revenue, earnings, stock-market performance, and growth in cash flow.

The *Business 2.0* ranking follows on the heels of another award received by Aeroflex—Top Performing Small Company as announced in *Aviation Week's* Top-Performing Aerospace Rankings (July 1, 2002). Aeroflex's growing sales and improved profits took them from the No. 5 position in 2001 to No. 1 in 2002.

"We are very proud of both these rankings," said Len Borow, executive vice president and COO of Aeroflex. "It is our vision to be the industry leader in our core businesses by focusing on total customer satisfaction. These awards show that a commitment to total customer satisfaction can and does positively impact growth."

Additional information concerning Aeroflex, Inc. can be found on the company's website at www.aeroflex.com.

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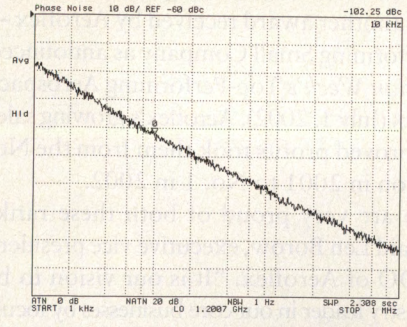
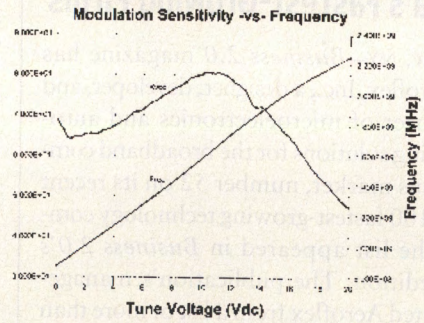
VC0790-2300T	2100-2500	1.0 - 4.0	-89 dBc/Hz	+5 V	+3 dBm	0.5 x 0.5 x 0.18 in.
VC0793-600T	400-800	0.0 - 20.0	-104 dBc/Hz	+12 V	+7 dBm	0.5 x 0.5 x 0.18 in.
VC0793-1500T	**1000-2000**	**0.0 - 20.0**	**-99 dBc/Hz**	**+12 V**	**+7 dBm**	**0.5 x 0.5 x 0.18 in.**

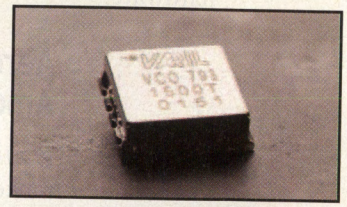
Actual data for VC0793-1500T

Phase noise from HP3852 for 1000-2000 MHz VCO



Tuning Sensitivity from HP3852 for 1000-2000 MHz VCO





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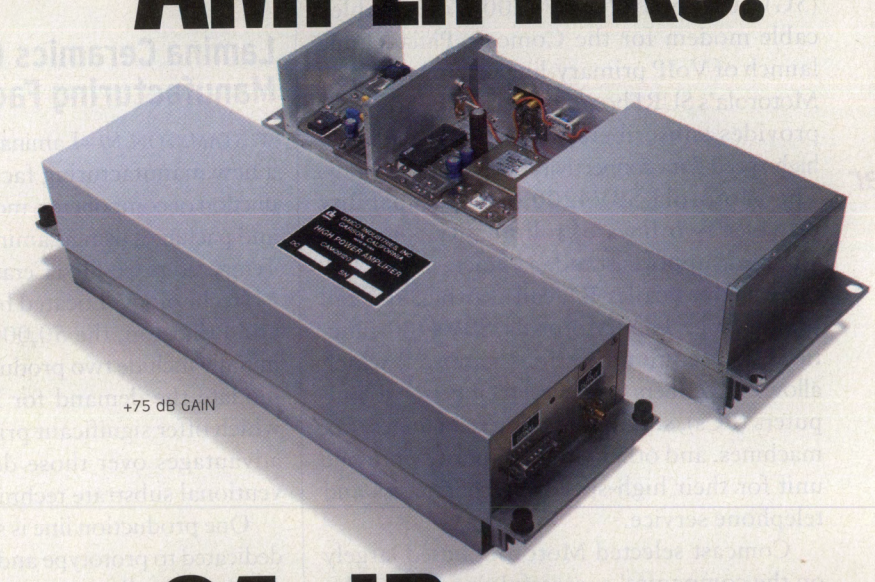

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VSWR In/Out			1.2:1		
P1 dB Comp.	63.5	64.0		dBm	
Harmonics Out II, III	60	65		dBc	
Gain Tracking		±0.2	±0.3	dB	Unit-to-unit
Phase Tracking		±2.0	±3.0	degree	Unit-to-unit
VSWR Withstand Under Full Power			∞:1		All phases
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Comcast Names Motorola To Supply VoIP Cable-Modem Equipment

HORSHAM, PA—Motorola, Inc.'s Broadband Communications Sector has been named a supplier of Voice over Internet Protocol (VoIP) cable-modem technology for Comcast Corp. Previously, Motorola was selected to provide VoIP-enabled cable modems for Comcast's recent Detroit VoIP service launch, as well as for Comcast system trials.

> "Motorola has been a valued voice-technology partner for over three years."

Motorola is supplying its fifth-generation (5G) SURFboard® SBV4200 VoIP-enabled cable modem for the Comcast Philadelphia launch of VoIP primary-line services. Built on Motorola's SURFboard platform, the SBV4200 provides subscribers with standards-based high-speed data connectivity and cable telephony. The Motorola SBV4200's voice capability provides two lines of toll-quality voice service and supports standard voice-service features such as caller ID, call waiting, and call forwarding. The Motorola SBV4200 functions as a communications gateway, which allows subscribers to connect their personal computers (PCs), standard analog telephones, fax machines, and other voice appliances into one unit for their high-speed Internet access and telephone service.

Comcast selected Motorola based largely on the companies' successful three-year relationship. In addition to the proven performance of its VoIP technology, Motorola has consistently demonstrated and provided a wide range of available services and technical support, support for PacketCable and compliance with DOCSIS 1.1 industry standards, and interoperability with other VoIP products and solutions.

"Motorola has been a valued voice-technology partner for over three years," said Steve Craddock, senior vice president of new media development at Comcast Cable. "Motorola's SURFboard platform provides proven, reliable, and interoperable data and voice technology. We're pleased to continue expanding our relationship to bring our customers new telephony services."

"Comcast's strategic deployment of VoIP technology is the latest example of their company's leadership in the broadband industry," commented John Burke, corporate vice president and general manager of Motorola Broadband's communication gateways business. "Motorola will continue to support Comcast with VoIP technology solutions that deliver the advanced services that their customers demand."

Comcast first commercially introduced VoIP primary-line services, using Motorola VoIP cable-modem technology, in its Detroit system in April 2002. Comcast now plans to introduce this service to other markets beginning in the second quarter of 2003. Comcast currently offers circuit-switched voice telephone service to approximately 40,000 customers in Michigan and Virginia.

Lamina Ceramics Opens New Manufacturing Facility

WESTAMPTON, NJ—Lamina Ceramics has opened a new manufacturing facility to increase production of components, modules, circuit boards, and packages using Lamina's proprietary Low Temperature Co-fired Ceramic on Metal (LTCC-M) technology. Located between Philadelphia and Princeton, the 50,000-sq.-ft. facility will initially include two production lines to accommodate the demand for LTCC-M products, which offer significant price and performance advantages over those developed with conventional substrate techniques.

One production line is semi-automated and dedicated to prototype and small-quantity production. A fully automated line for high-volume applications is also part of the new facility. Lamina can design the basic substrate and populated circuit board, in addition to providing post-processing assembly services. With the new facility, LTCC-M prototypes can be delivered in as little as four weeks.

"Due to the strong interest and initial response from a variety of customers, we needed to expand our production capabilities to most effectively meet our customers' requests. Our new facility has also been developed to accommodate the increased future demand we expect for products using our LTCC-M technology," said Taylor Adair, president of Lamina Ceramics.

The expected increased demand is due to the inherent advantages of LTCC-M, a multilayer ceramic-on-metal technology that solves a host of electrical and mechanical design challenges associated with high-performance components, modules, circuit boards, electronic packages, and hybrid systems.

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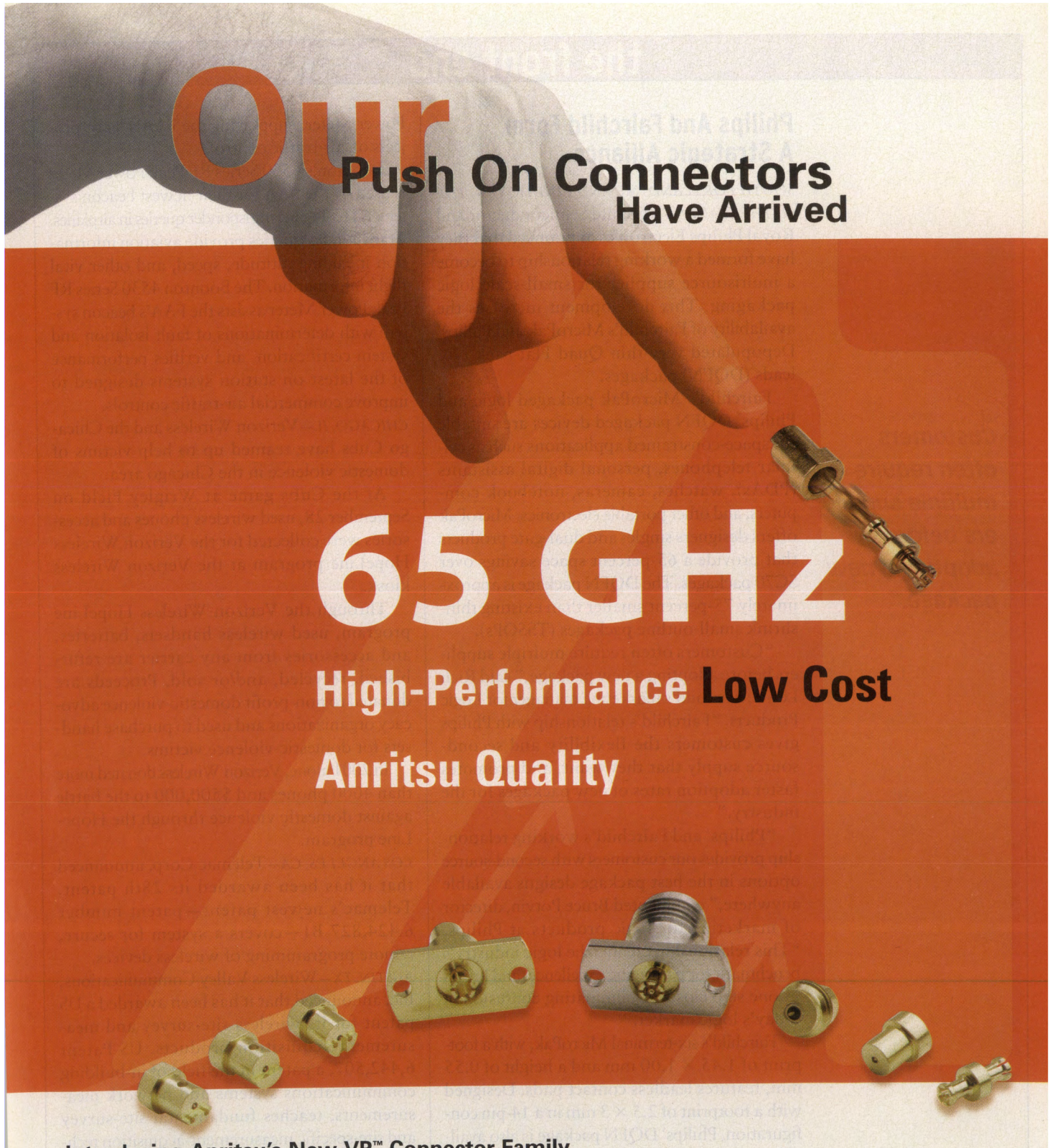

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Philips And Fairchild Form A Strategic Alliance

SOUTH PORTLAND, ME AND EINDHOVEN, THE NETHERLANDS—Fairchild Semiconductor and Royal Philips Electronics announced that they have formed a working relationship to become a multisource supplier for small-scale logic packaging. This development increases the availability of Fairchild's MicroPak and Philips' Depopulated very-thin Quad Flat-pack No-leads (DQFN) packages.

"Customers often require multiple suppliers before adopting a new package."

Fairchild's MicroPak packaged logic and Philips' DQFN packaged devices are suitable for space-constrained applications such as cellular telephones, personal digital assistants (PDAs), watches, cameras, notebook computers, and other portable electronics. MicroPak offers designers single- and dual-gate products that provide a 65-percent space savings over SC70 packages. The DQFN package is approximately 75-percent smaller than existing thin-shrink small-outline packages (TSSOPs).

"Customers often require multiple suppliers before adopting a new package," said Rich Lewis, Fairchild's marketing manager for Logic Products. "Fairchild's relationship with Philips gives customers the flexibility and second-source supply that they want, and promotes faster adoption rates of new packages for the industry."

"Philips' and Fairchild's working relationship provides our customers with second-source options in the best package designs available anywhere," commented Bruce Potvin, director of marketing for logic products at Philips. "This relationship creates the logic industry's benchmark for packaging excellence, and brings us one step closer to eliminating confusion in today's logic market."

Fairchild's six-terminal MicroPak, with a footprint of 1.45 × 1.00 mm and a height of 0.55 mm, features leadless contact pads. Designed with a footprint of 2.5 × 3 mm in a 14-pin configuration, Philips' DQFN package is also available in 16- and 20-pin options.

Kudos

PARAMUS, NJ—Wireless Telecom Group, Inc. announced that its wholly owned subsidiary, Boonton Electronics, has been awarded an additional contract with the Federal Aviation Administration (FAA) for Boonton's 4530 Series RF Peak Power Meter, supporting the FAA's latest projects on air-traffic control.

Boonton's 4530 Series RF Peak Power Meter is used by the FAA for their newest beacon system, ATCBI-6, for transponder queries in airplanes. Transponder queries provide aviation information including altitude, speed, and other vital flight information. The Boonton 4530 Series RF Peak Power Meter assists the FAA's beacon system with determinations of fault isolation and system certification, and verifies performance of the latest on station systems designed to improve commercial air-traffic controls.

CHICAGO, IL—Verizon Wireless and the Chicago Cubs have teamed up to help victims of domestic violence in the Chicago area.

At the Cubs game at Wrigley Field on September 28, used wireless phones and accessories were collected for the Verizon Wireless HopeLine program at the Verizon Wireless kiosk.

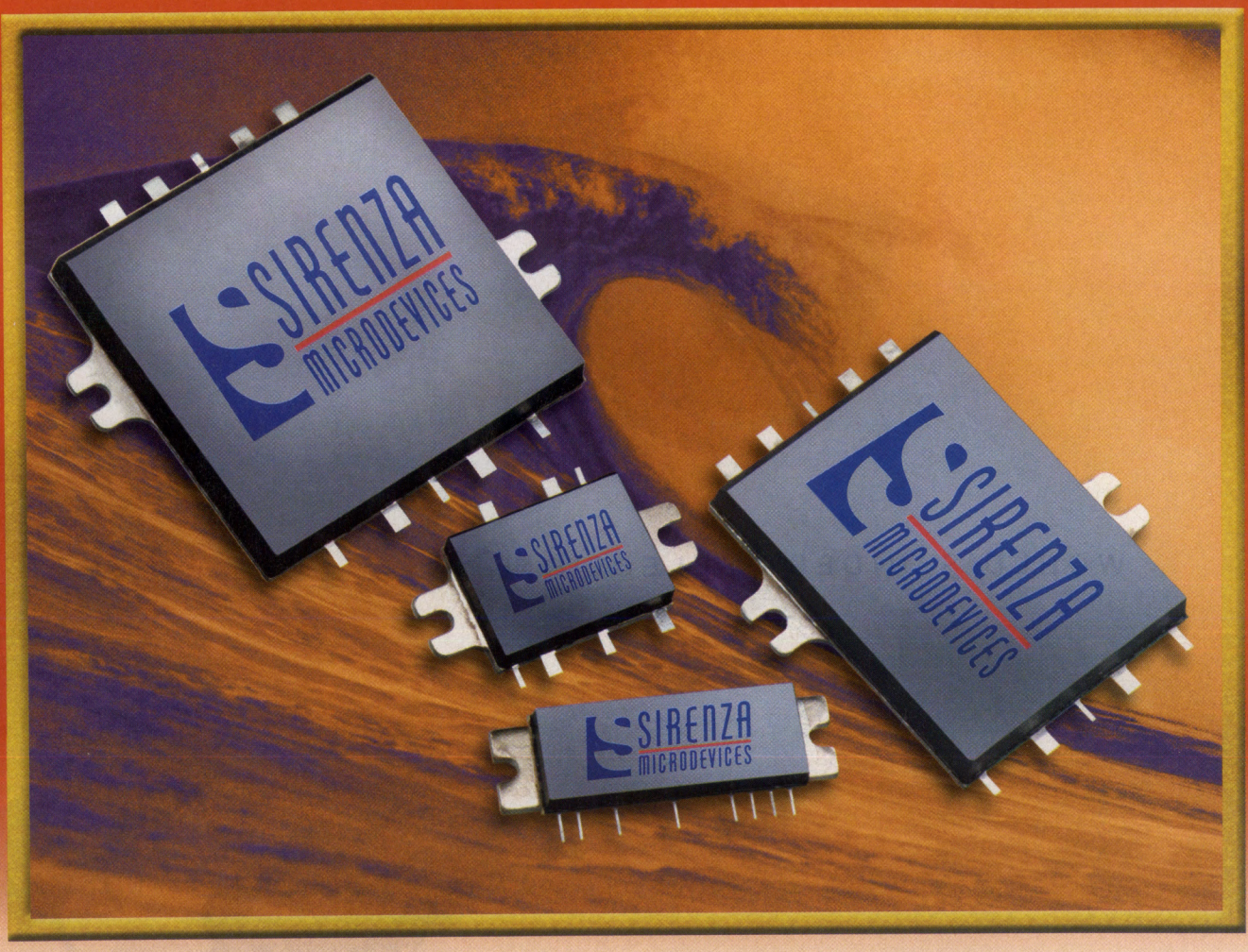
Through the Verizon Wireless HopeLine program, used wireless handsets, batteries, and accessories from any carrier are refurbished, recycled, and/or sold. Proceeds are donated to non-profit domestic-violence advocacy organizations and used to purchase handsets for domestic-violence victims.

In 2001 alone, Verizon Wireless donated more than 4000 phones and $500,000 to the battle against domestic violence through the HopeLine program.

LOS ANGELES, CA—Telemac Corp. announced that it has been awarded its 28th patent. Telemac's newest patent—patent number 6.424,827 B1—covers a system for secure, remote programming of wireless devices.

AUSTIN, TX—Wireless Valley Communications, Inc. announced that it has been awarded a US patent for its wireless site-survey and measurement-acquisition products. US Patent 6,442,507, a patent in the field of in-building communications systems and network measurements, teaches fundamental site-survey and site-specific measurement-acquisition techniques developed by Wireless Valley. The patent covers inventions used in the InFielder®, InFielder® personal digital assistant (PDA), and LANFielder® measurement products that work within or remotely with Wireless Valley's SitePlanner® in-building design product.

OVERLAND PARK, KS—Sprint announced that it has earned the TMC® (Technology Marketing Corp.) Labs innovation award for a Sprint video telephony product. MRF



More Power to You

Sirenza adds integrated power modules to its comprehensive RF component line

Xemod is now part of Sirenza Microdevices. As the originator of 'plug-n-play' high-power solutions for linear power-amplifier designs, Xemod extends Sirenza's power-component product line to significantly higher power levels and operating voltages for wireless network-equipment applications.

Xemod originated the QuikPAC® line of matched modules for use as pre-drivers, drivers, and output stages in wireless power amplifiers. QuikPAC modules are offered in one- and two-stage configurations for medium-power (10–35 W) and high-power (60–200 W) applications. The module sizes are standardized so designers can easily design for multiple platforms with the same or similarly dimensioned modules.

Ramp-up times from design concept through production are drastically reduced and time-to-market is greatly improved. As a result, the QuikPAC module significantly reduces design and manufacturing costs.

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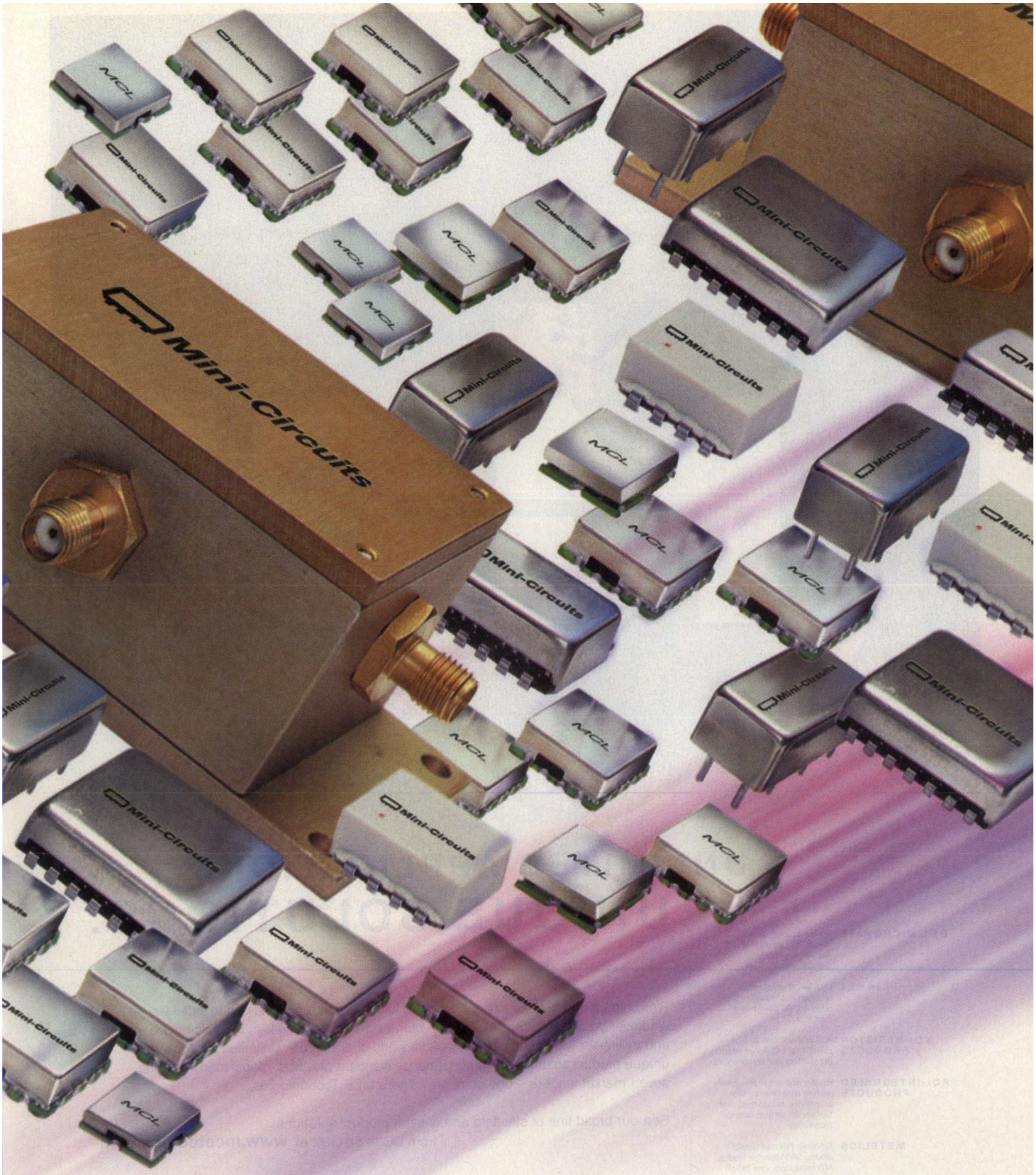

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Weinschel Celebrates 50 Years of Excellence

One of the mainstays of the microwave industry has seen its share of changes during five decades, while continuing to play a leadership role in attenuator-based technology.

Fifty years is a long time for a company in any industry. In the microwave industry, for example, a mere handful of companies can trace their roots back one-half century, making this achievement by Weinschel Corp. (Frederick, MD) all the more meaningful. Founded as Weinschel Engineering and now known as MCE/Weinschel Corp., the company has prospered during a period when many companies began and failed, building a strong foundation upon its high-frequency attenuator technology.

JACK BROWNE
Publisher/Editor

Weinschel, which takes its name from founder Dr. Bruno O. Weinschel **(see sidebar, "The Founder")**, began life in 1952 in Kensington, MD. The company offered the world's first commercially available coaxial attenuators, and quickly established a solid reputation for the quality of its attenuator products. Within the first half of its history, the firm had already designed and developed comprehensive product lines in fixed attenuators, continuously variable attenuators, step attenuators, motorized step attenuators, resistive power splitters, terminations, coaxial connectors, and adapters. In support of its products, the company also set standards for attenuation and power measurements, including more than 60 technical articles in the 1978-1979 catalog.



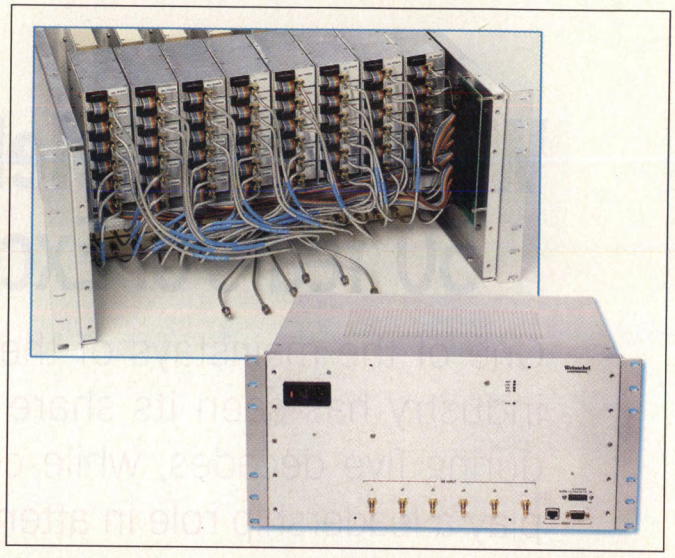
1. MCE/Weinschel Corp., located in Frederick, MD, is one of the longest-running success stories in the microwave industry, reaching its 50th year of operation.

That measurement expertise, combined with the variety of components developed at Weinschel, led to the development of proprietary measurement tools, such as attenuation-measurement and power-meter-calibration instruments, which would eventually be offered to the general public as commercial products, such as the model VM-3 an VM-7 attenuator and signal-generator calibrators and the later model VM-24 signal-generator calibrator (see *Micro Waves*, May 1982, Cover). The VM-7 was an advanced 30-MHz receiver (Rx) with –110-dBm sensitivity and 110-dB wideband dynamic range. The VM-24, which combined six measurement instruments including a frequency counter, signal source, and power meter, operated from 0.01 to 18 GHz.

In August 1986, Dr. Weinschel agreed to sell the company to the British company Lucas Industries, Inc. The company had grown to 259 employees by that time, working within a 50,000-sq.-ft. facility set on 19 acres in Gaithersburg. Lucas would acquire other American electronics companies, including Aul, EPSCO, and Zeta.

Weinschel would experience relative stability for approximately a decade

following the Lucas acquisition. The company added to its component lines, offering higher-power fixed coaxial attenuators and terminations to 500 W and 40 GHz; continuously variable, manual, and programmable step attenuators; power dividers; directional couplers; coaxial adapters; blind-mate connector systems; phase shifters; and custom subsystems. In 1994, Weinschel Corp.'s Quality Management system was approved to ISO 9001, EN29001, BS5750-Part 1, and ANSI/ASQC Q9001-1994 standards.



2. Weinschel, which has built on its subsystem business, now offers complex systems such as this assembly for testing IEEE 802.11 WLANs.

But much would change in 1995, a period during which the company would change hands twice within a period of months. "Within one 12-month period, we had three different owners: Lucas, Sierra Technologies, and MCE Technologies," notes Bob Stephens, Weinschel's president and CEO. Lucas had chosen to focus on its core business groups in aerospace systems and subsystems, and to sell off its component subsidiaries, such as Weinschel.

The Weinschel that emerged under MCE Technologies **(Fig. 1)** remains very diversified in terms of product lines, regions, number of customers, types of customers, markets (military, commercial, mobile, satellite, etc.), and applications **(see sidebar, "MCE At A Glance")**. "We have maintained the foundations of the company, which is the coaxial attenuators," notes Jimmy Dholoo, vice president of engineering, "but we have expanded our technologies and product lines." Examples of the company's responsiveness to changing technical requirements are its lines of low-intermodulation (IM) attenuators and its patented blind-mate connectors with flush-mounted contacts, which are capable of operating to 50 GHz. Dholoo and his engineering team regularly set new standards for attenuation products, introducing novel developments such as a DC-to-40-GHz, 20-W attenuator that is currently unavailable from any other supplier.

Although the company is firmly rooted in designing and manufacturing precision components, for many years it was thought of as a instrument house. "People still think we are in the instrument and calibration business," says Bob Stephens, who mentions an incident at a trade show when a visitor to the company's booth asked whether Weinschel was the company that "calibrates for NIST." Jokingly, Stephens suggested that the visitor share this message with everyone he knows. "Actually, we've worked very hard to change that image," notes Stephens. The instrument lines were sold off in 1997, and the company returned its focus to attenuators. "We've tried to build upon our core competencies, the attenuators, but also build upon our subsystem business," says Stephens. "We have made a successful transition from being a test business to being a component and subsystem business," he adds. "We are the subsystem of choice for such leading telecommunications companies as Ericsson, Motorola, and Nortel," reveals Stephens, "but our business starts with the attenuators."

As Stephens recalls, "We weren't really looking to redefine the company [when the instrument lines were sold off], but we had a lot of resident expertise left in the company from the instrumentation period, such as the ability to do packaging, bus-control interfaces, and highly integrated subsystems. Those people were still here, but we were no longer in the measurement business, so we found a way to use all of this design capability in the subsystem products."

Frank MacLean, the vice president of operations, initially joined the instrumentation group in 1987, during the company's years of peak employment (approximately 300 people) as the com-

The Founder

JACK BROWNE
Publisher/Editor

MCE/Weinschel Corp. began life as Weinschel Engineering, named after its founder Dr. Bruno O. Weinschel. Dr. Weinschel steered the company through its first 35 years before selling the company to Lucas Industries in 1986. In addition to his entrepreneurial skills, Weinschel has always been an "engineer's engineer," having developed numerous standard measurement techniques for power and attenuation while running his company. Dr. Weinschel sat on the IEEE Standards Committee as vice chairman, and helped develop such standards as the "IEEE Standard Specifications and Test Methods for Fixed and Variable Attenuators, DC to 40 GHz." He was named President of the IEEE beginning January 1, 1986, and also served as IEEE Secretary and IEEE Vice-President for Professional Affairs. Although no longer associated with Weinschel, Dr. Weinschel continues to work within the microwave industry.

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S3W2	S3W5	N3W5	3	±0.40
S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	±0.60
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	±0.60
S10W2	S10W5	N10W5	10	±0.60
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S15W2	S15W5	N15W5	15	±0.60
S20W2	S20W5	N20W5	20	±0.60
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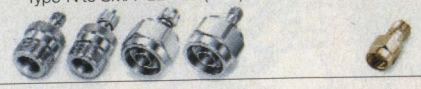

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MCE At A Glance

JACK BROWNE
Publisher/Editor

Established in 1994, MCE Technologies (www.mcetechinc.com) consists of companies strategically located throughout North America, Europe, and Asia, under the helm of John Smucker. Seven business units and 10 facility locations support research, design, manufacturing, and test requirements for standard and custom product lines. In addition to Weinschel, the companies include MCE/Inmet (Ann Arbor, MI, www.inmetcorp.com), MCE/Metelics (Sunnyvale, CA, www.metelics.com), MCE/KDI-Integrated Products (Whippany, NJ, www.mcekdi-integrated.com), MCE/KDI-Resistor Products (Whippany, NJ, www.mcekdi-resistor.com), MCE/DML Microwave (Southend-on-Sea, Essex, England, www.dmlmicro wave.com), and MCE Technologies-Nanjing (Nanjing, PRC). The companies can draw advice from a technical advisory board consisting of scientists from the University of Michigan, such as Dr. George Haddad, Dr. Jack East, and Professor Dimitris Pavlidis. The MCE group of companies encompasses a wide range of product areas, including diodes, capacitors, amplifiers, resistive-film products, attenuators, terminations, isolators and circulators, DC blocks, bias tees, connectors, power dividers/combiners, detectors, switch subsystems and matrices, and attenuation subsystems, as well as serving a variety of markets, such as wireless mobile, fixed-wireless and broadband communications markets, defense electronics, and test and measurement markets.

pany began to migrate from a two division operation into a single focused business, a three-year "evolution plan," was initiated to completely redefine and modify the operations. The initial phase involved a complete review of the existing vertical integration that existed and continued to expand on an annual basis. Each area was reviewed and justification for continuation was either presented or a recommendation for elimination was issued. The first area was the plating shop. Weinschel worked with the plating supervisor on developing the capability as his own, independent business and then sold the capability to him, becoming his first "arms-length" customer and continuing to use his services today. The next area was painting and again the company set the capability up as a standalone business for the supervisor and continues to use his business today. The harder area was the machine shop,



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which in many regards had more capabilities than a small aircraft facility. Says MacLean, "We stuck a pin on a map in Gaithersburg and drew a 60-mile radius, with our intent and plan to develop a competent source of supply for the majority of the fabrication and machine services that were resident within the facility. Over a relatively short amount of time a strong and technical supplier base had been qualified and we were able to reduce the reliance on and need for our large machine and fabrication shop. Today the shop is used for tight tolerance, short run and new product development functions."

With the combining of the instrumentation and components groups into a single facility in 1989, Weinschel again realized that change was needed in the way products were manufactured. The first step was to eliminate "end of the line" inspection as a "checker and criticizer role." MacLean remarks, "We initiated intensive quality assurance, TQC, and TQM training for all levels of the company. Employees were challenged to recommend change and empowered to stop production on any product that was not in compliance with the drawing or had very low yields throughout the assembly and test process."

Production was then changed from lines of benches to product cells, where the employees were trained and developed to fully understand the products, inspect to established procedures, view the customers as theirs, and were encouraged to accept full responsibility for meeting schedules and significantly improving quality and profitability for each product line. The changes were painful at first, but today the results are real: increased production with significantly less people, outstanding quality and customer satisfaction, and, most important, a highly skilled, effective, and involved workforce.

In its 50 years as a business entity, Weinschel has boasted many good people. Surprisingly, the company was able to keep most of its people even when moving from Gaithersburg to Frederick. "We looked around the whole area for a facility and ended up moving about 25 to 30 miles from Gaithersburg, but the average commute actually decreased," says Stephens. "When Lucas bought us, we had limited time to move out of Gaithersburg. It was almost like a full-time job for Frank to find a new facility," he adds.

Remarkably, some of the company's earliest employees still contribute significantly to Weinschel's progress, including Virginia Jenkins, her sister Elva Duval, and their friend, Sandy Black. Virginia Jenkins, 44 years with Weinschel, joined the company when

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she was only 20 years old. "I've learned a great deal here from the people I've worked with, and from the managers," she says. "I've been through four different owners and have seen a lot of changes, but it has been good with all of them. You learn to go along with any changes they make." Jenkins' sister, Elva Duval, has been part of Weinschel for 43 years. "I've worked with the company since 1959," she recalls. "I will certainly miss this company when I retire." She thinks of Weinschel as her family, noting that "they bend over backwards to help their people, much like a family. If you've been here and you've done your job, they are as good to you as you are to the company."

Compared to the two sisters, Sandy Black is a relative newcomer, with a "mere" 31 years at Weinschel. "I started on the assembly line in 1971, became a team leader for high-reliability attenuators, then went to work on a manufacturing engineering cell for special jobs. Then Frank MacLean asked me to come to work in operations for manufacturing engineering. It's always been interesting and fun," she says.

Virginia Jenkins has a special place in her heart for the people of Weinschel: "I had a triple-bypass operation in 1998 and was off from April 1998 to February 1999. If it hadn't been for this company and the people, from the president on down, calling me...it made it much easier for me to come back."

Another member of the Weinschel 40-year club, Carol Benton, is group leader for the fixed-attenuator group. "When I started, we only had the 1- and 2-W models," she recalls. "But now we go up to 1000 W."

Recent growth at Weinschel can be traced to the efforts of the subsystems product group, led by one of the company's newest employees, Warren Gruber, vice president for business development of Subsystems. "These products have now evolved to test subsystems for telecom organizations like Motorola, Nortel, Ericsson, Samsung," states Gruber. His group has expanded to take on contracts for complex switch matrices such as integrated systems that include the backup switching networks for broadband network original-equipment-manufacturers (OEMs) in their cable headend systems, and most recently has delivered the first signal simulator for IEEE 802.11 wireless-local-area-network (WLAN) systems **(Fig. 2)**.

Weinschel's communications manager, Barry Newlin, points out that the company philosophy can be summarized in just three words: tradition, quality, and innovation. "Reputation is something that wraps around all three of those words," notes Newlin. MRF

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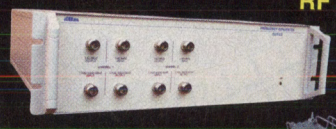
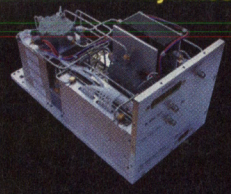


RF Converters



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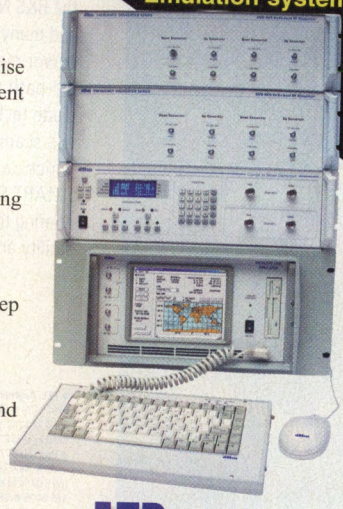

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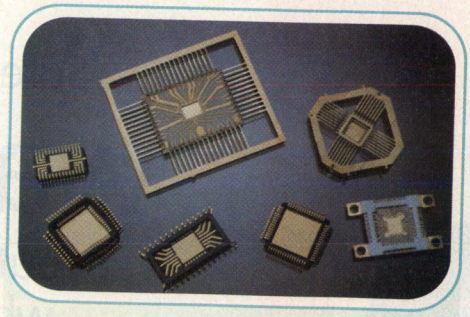

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Anaren Microwave, Inc., 6635 Kirkville Rd., East Syracuse, NY 13057; (315) 432-8909, FAX: (315) 432-9121, Internet: www.anaren.com.

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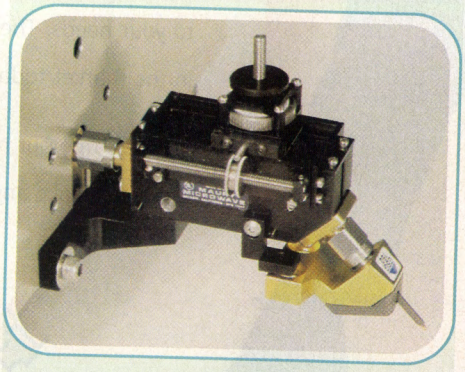
ANAREN MODEL XB625



FOX ELECTRONICS MODEL F4109



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Oscillators Offer 22-mA Input Current

THE F4100 SERIES of miniature surface-mount crystal oscillators includes model F4107, with a stability of ±15 PPM and model F4109, with a stability of ±10 PPM. The oscillators maintain these stabilities inclusive of operating temperature range, input voltage change, load change, aging, shock, and vibration. These two +3.3-VDC high-performance-complementary-metal-oxide-semiconductor (HCMOS) oscillators have a standard operating temperature range of –10 to +70°C with an optional –40 to +85°C range available for the F4107. Output symmetry is 45 to 55 percent at +1.65 VDC over the frequency range of 1.8 to 50.0 MHz. Input current is 22 mA maximum.

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Tuners Span 8 To 50 GHz

THE MT902 PROBE mount and prematch tuners operate from 8 to 50 GHz in three configurations: a high-frequency 21.5-to-50.0-GHz prematch tuner, a low-frequency 8.0-to-21.5-GHz prematch tuner, and an 8-to-50-GHz wafer probe mount. VSWR range is 10.1 minimum and insertion loss is 0.007 f GHz. Repeatability is 40 dB minimum and power handling is 10 W continuous wave (CW), or 0.5 kW peak. Connectors are 2.4 mm and weight is 2.7 oz. The tuners are highly stable, low-loss wafer probe mounts used in on-wafer device-characterization applications. By extending a wafer probe away from the tuner body, these mounts create additional clearance for proper probe alignment.

Maury Microwave Corp., 2900 Inland Empire Blvd., Ontario, CA 91764-4804; (909) 987-4715, FAX: (909) 987-1112, Internet: www.maurymw.com.

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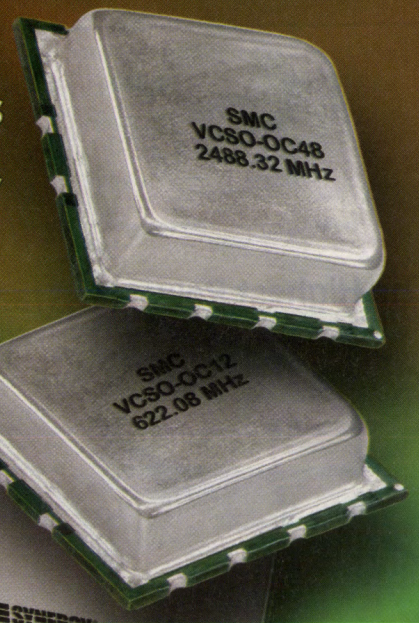

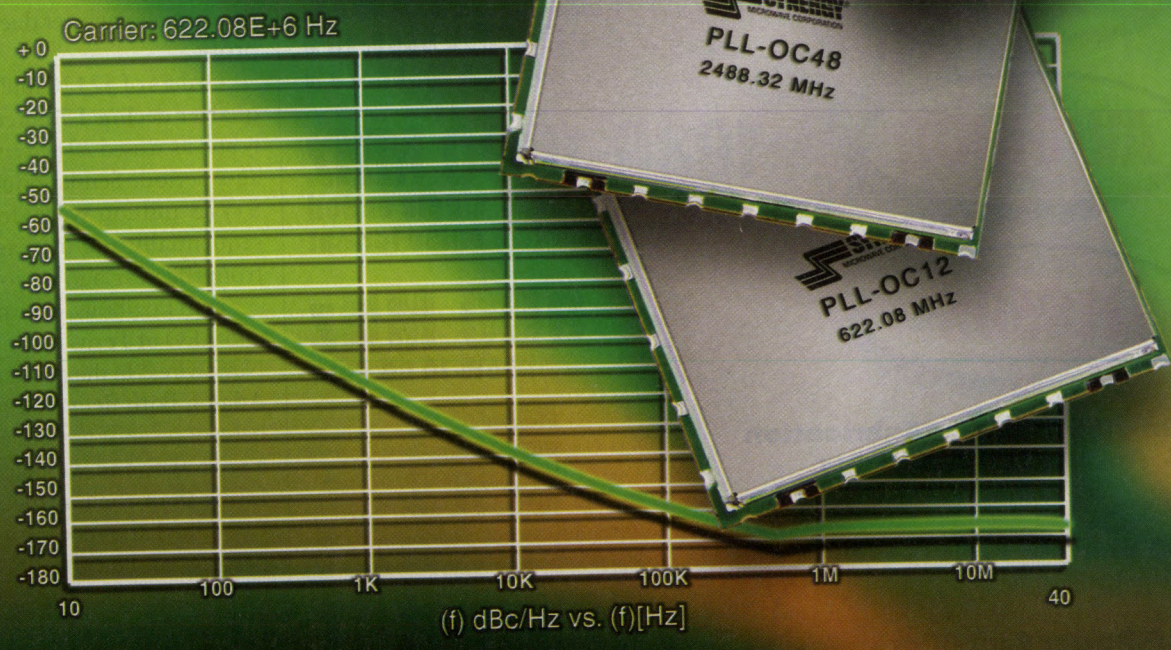

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TI's Revenue Is Increasing

TEXAS INSTRUMENTS, INC. recently reported that its third-quarter revenue increased 4 percent sequentially and 22 percent compared with the year-ago period, according to a report from PR Newswire.

Semiconductor revenue grew 4 percent sequentially and 26 percent compared with the year-ago period, driven by increased shipments in digital-signal processors (DSPs) and Analog. Educational & Productivity Solutions (E&PS) revenue grew 21 percent sequentially, due to higher seasonal back-to-school shipments of graphing calculators, and 1 percent compared with the year-ago period. Sensors and controls revenue declined 6 percent sequentially and grew 7 percent compared with the year-ago period.

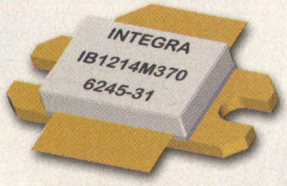
Research-and-development (R&D) expense increased compared with the second quarter and the year-ago quarter due to increased product-development activity in the Semiconductor Division.

Operating profit declined sequentially due to higher operating expenses, in addition to lower gross profit. Operating profit increased compared with the year-ago quarter due to higher gross profit.

Orders of $2120 million in the third quarter declined 7 percent sequentially and increased 29 percent from the year-ago period. Semiconductor orders of $1773 million were down 5 percent sequentially and increased 36 percent from the year-ago period.

Tom Engibous, chairman, president, and CEO of Texas Instruments, told PR Newswire, "In the quarter, TI's DSP and Analog both delivered more than 30-percent revenue growth compared with a year ago, and we believe both grew faster than their respective markets. Combined, they comprise more than 70 percent of TI's total Semiconductor revenue."

Regarding markets and applications, Engibous stated, "Semiconductor revenue was up across a broad range of products. Wireless especially remained strong, delivering its fifth-consecutive quarter of sequential growth as customers continue to embrace new, advanced cell phones with color screens, and as TI chip sets further penetrate OEM and ODM customers." MRF



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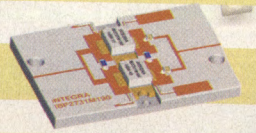
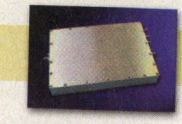


RF Power Amplifiers



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LT5511
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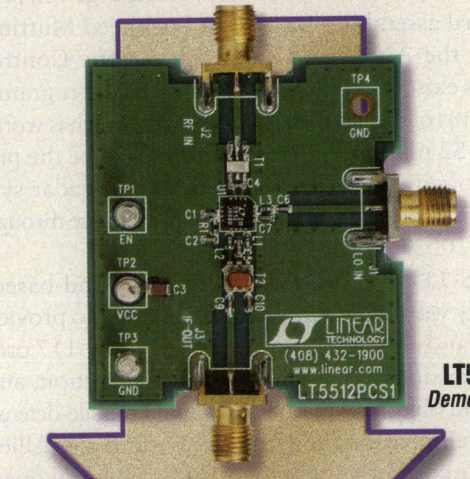

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Features

	Upconverter LT5511	Downconverter LT5512
Conversion Gain	0dB	1dB
IIP3 950MHz 1900MHz	+17dBm +15.5dBm	+21dBm +17dBm
IIP2	+52dBm	NA
SSB Noise Figure	15dB	13.3dB
LO-Input Leakage	NA	-53dBm
LO-Output Leakage	-46dBm	-46dBm
LO Drive Level	-15 to -5dBm	-15 to -5dBm
Supply Current	56mA	57mA
Supply Voltage	4V to 5.25V	4.5V to 5.25V
Package	16-Lead SSOP	4mm x 4mm QFN

Data Sheet

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CONTRACTS

LaBarge, Inc.—Announced that it was awarded contracts valued at $2.7 million from Lockheed Martin Naval Electronics & Surveillance Systems in Syracuse, NY. LaBarge will produce circuit-card assemblies for two of Lockheed Martin's radar systems, the AN/FPS-117 and Air Traffic Control (ATC). Options exist for additional work on both programs.

Under the terms of the AN/FPS-117 contract, which is worth approximately $2 million, LaBarge continues to be the primary supplier of circuit-card assemblies for the radar system. Production is to begin this month and will continue through the summer of 2003.

The AN/FPS-117 is a NATO-certified, ground-based, long-range, early warning radar system. Designed to provide air surveillance and air-traffic control, the AN/FPS-117 provides three-dimensional (3D) data on range, direction, and altitude of in-flight objects, with optional air and missile-defense capability. Developed for the US, NATO, and the Allied Forces, there are currently more than 120 systems in operation worldwide.

Production of ATC circuit cards began in August and is expected to continue through the summer of 2003. The ATC contract is valued at approximately $700,000. ATC is Lockheed Martin's first commercial air-traffic-control radar system, which is based on the company's military radar system known as ASPARCS (Air Surveillance and Precision Approach Radar Control System). The civil aeronautics branch of the Colombian Ministry of Transportation will be the first customer to deploy Lockheed Martin's ATC radar system. ATC provides air-traffic controllers with lightweight, mobile radar to enhance all-weather landing capabilities.

LaBarge will produce the circuit cards for both contracts at its Tulsa, OK facility.

Eagleware—Was awarded a Small Business Innovation Research (SBIR) Phase II contract by the US Air Force for enhancements to the GENESYS integrated system-synthesis-circuit design environment. This 24-month contract will fund the development of synthesis technology that is not available in the market today.

During Phase I, Eagleware developed the system architecture, created a direct filter synthesis program (S/FILTER), and proved the feasibility of a complete design-system environment. Under Phase II, Eagleware will complete the system-synthesis-circuit design environment, providing a single software system for the integrated synthesis and simulation of RF and microwave systems.

The result of the Phase II work will dramatically increase engineers' ability to translate performance specifications into working designs, thus increasing the speed of design while lowering the cost of design. Engineers will be able to rapidly design efficient analog, RF, and microwave circuits seamlessly from system design to physical realization. The use of a single design environment reduces the cost of prototyping and speeds the delivery of sophisticated, state-of-the-art intelligence, surveillance, and reconnaissance (ISR) systems. Phase II expands Eagleware's synthesis program to include other types of circuits for which no tools currently exist.

FRESH STARTS

Silicon Wave—Announced that Qualcomm has qualified Silicon Wave's SiW1702TM Radio Modem for use with Qualcomm CDMA Technologies' Mobile Station Modem (MSM) chip sets with an integrated Bluetooth baseband. Qualcomm's MSM code-division-multiple-access (CDMA) chip set licensees will now be able to integrate Bluetooth wireless functions into their mobile phones by adding the SiW1702 Radio Modem.

Allen Telecom Inc.'s MIKOM Division—Signed an agreement with BT Wholesale, a business unit of British Telecommunications plc, to provide a multi-user microcell distributed antenna system (MIDAS) in the United Kingdom. MIDAS provides a multi-technology, shared, urban deployment system for second-generation and third-generation (2G and 3G) networks that allows multiple radio operators to use the same network infrastructure.

MIDAS's distributed antenna system technology was specifically designed by MIKOM for joint use by wireless service providers. MIDAS connects low-power transmission mounted on existing street infrastructure, with base stations for wireless devices installed in a central equipment room. MIDAS is the first antenna coverage system in operation that satisfies the requirements of established technologies including GSM 900, GSM 1900, and those of the new UMTS and WLAN 802.11 radio networks.

MIKOM has begun feasibility studies for the first 600 sites and believes that the market could extend to more than 3500 2G and 3G cellular network sites.

MIKOM will plan the construction projects, coordinate the execution and installation, and manufacture the antenna equipment. BT will be responsible for the network and for sales and marketing to local wireless service providers.

Analysys—Has unbundled its research portfolio and is making it available for credit-card purchases through an online store at www.research.analysys.com/store.

The store provides instant 'pay-per-view' access to hundreds of company profiles, country reports, and country market forecasts, along with Analysys's catalogue of market-trend studies covering mobile and fixed telecoms, as well as billing markets.

The online store is designed for customers with ad-hoc research requirements that do not want, or need, to commit to a subscription-based service, but prefer the flexibility of instant desktop delivery and payment by credit card. MRF

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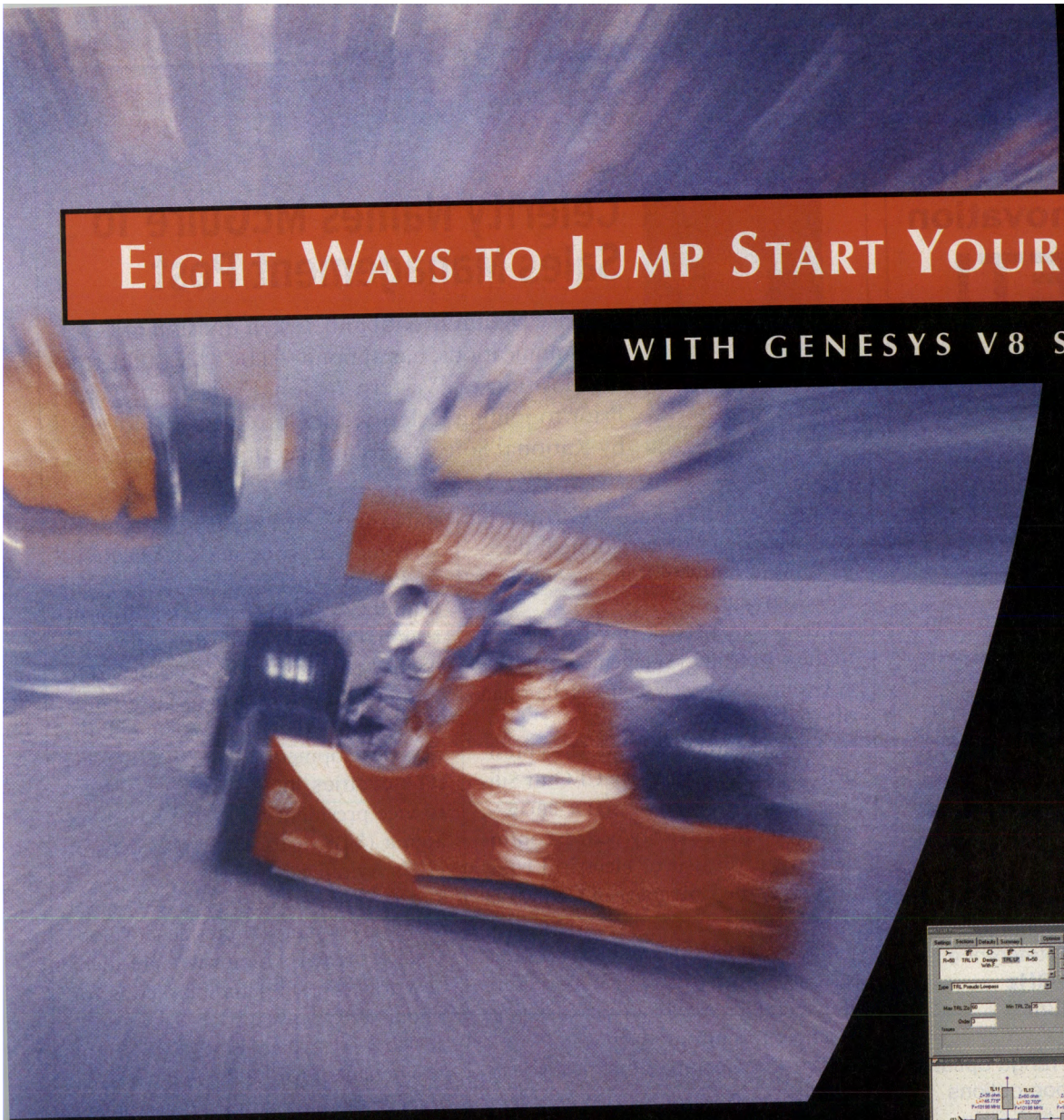

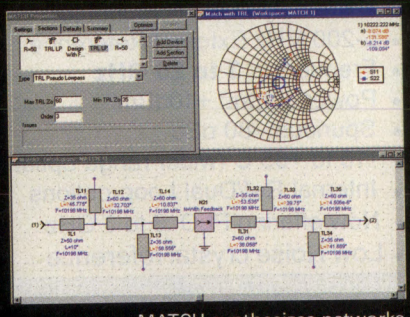

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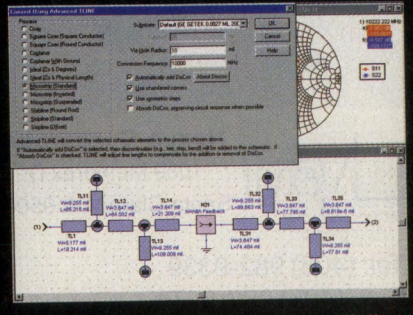

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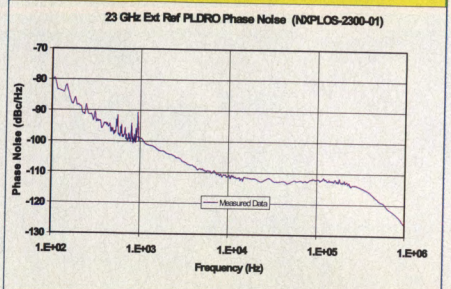

Phase Noise at 23 GHz (Typical)

100 Hz	**- 80 dBc/Hz**
1 KHz	**-100 dBc/Hz**
10 KHz	**-110 dBc/Hz**
100 KHz	**-112 dBc/Hz**
1 MHz	**-127 dBc/Hz**

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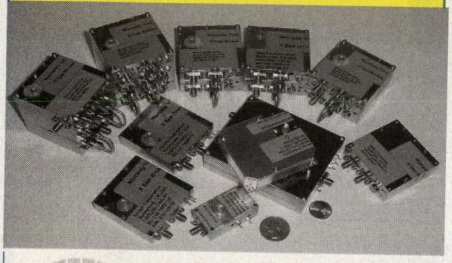

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Celerity Names McGuire To Sales Management Post

Celerity Digital Broadband Test, a division of L-3 Communications, has appointed LUCY MCGUIRE to the position of Western regional sales manager. Prior to joining Celerity, McGuire was employed by Rational Software as an account executive.

StorageNetworks, Inc.—DAVID DEW to chief technology officer; formerly director of BMC Software's Storage Solutions Development.

UK Government—DR. DAVID CLEEVELY to the Spectrum Management Advisory Group (SMAG); remains as chairman of Analysys.

MEMGen Corp.—VACIT ARAT to president and CEO; formerly CEO of Silicon Value, Inc. Also, ELLIOT R. BROWN, PH.D. to to the advisory board; continues as a professor of electrical engineering at the University of California at Los Angeles.

TI-RFid Systems—MICHAEL KNEBELKAMP to the position of strategic marketing manager; formerly strategic marketing manager for automotive.

Network Associates, Inc.—GREGORY A. JORGENSEN to senior vice president of marketing; formerly senior consultant with IBM's Solutions and Strategy Division.

TippingPoint Technologies, Inc.—GEOFFREY W. KREIGER to CFO; formerly CFO of DTM Corp.

Digital Power Corp.—HAIM YATIM to CFO; formerly a partner at Ernst & Young in Israel.

CAP Wireless, Inc.—MARK E. LAMPENFELD to executive vice president; formerly president of Microsource, Inc.

Advanced Microtek—JOHN HALLS to tool maker; formerly machine tool maker at Prestech Ltd. Also, JOHN O'NEILL to tool maker; formerly tool maker for RJL Engineering.

MCE Technologies—NORM HANSEN to vice president of sales and marketing for the worldwide sales organization at MCE/Inmet, Inc.; formerly regional director of business development. Also, RAND SKOPAS to regional director of sales and marketing at MCE/KDI Resistor Products for the Military, Asia/Pacific, and Canadian customers; formerly regional director of business development. In addition, CRAIG LINDBERG to the position of president of MCE/Inmet Corp.; formerly vice president of business development.

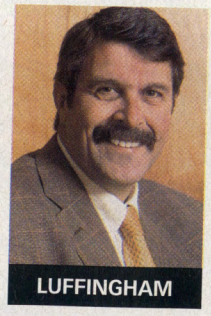
ITT Industries, Inc.—STEVEN F. GAFFNEY to vice president for Value-Based Six Sigma (VBSS); formerly president of ITT's Avionics Division.

Kyocera Wireless Corp.—DAVE WHALEN to the position of vice president of global sales; formerly senior vice president of worldwide sales and marketing for Signalsoft/Openwave.

Verizon—KATHRYN BROWN to senior vice president for Public Policy Development and International Government Relations; formerly chief of staff at the Federal Communications Commission (FCC).

OnRamp Communications Corp.—KATIE BINZ to public relations assistant; formerly studied Marketing Communications with a concentration in Public Relations at California Lutheran University.


BINZ


LUFFINGHAM

Axiom Navigation, Inc.—MARK LUFFINGHAM to director of European sales; formerly European sales manager for Magellan Systems Corp. MRF

...And then I saw Heather at the mall talking to Brandon and she was so wearing her mother's sweater and I'm like "Hello?" that's so Kate Jackson and so totally un-Lucy Lu, you know? Anyway, she says to Brandon that I think his older brother Josh is a hottie and I'm like my God I could die because I so think Josh is USDA grade A prime but now I can't even go over to their house because I'm like so freaked out about Heather saying that and normally I'm like very articulate you know? But now I can't even put ga and ga together like I've seen puppies speak better than that. So I think maybe I should bark—at least that proves I have vocal cords. But what's that say about me ... that I'm a dog? Hello? Look at these teeth. Look at this hair. I am not a dog, girl!

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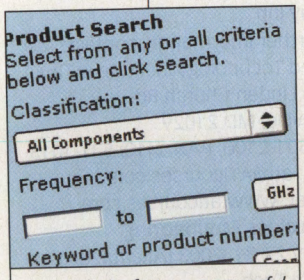

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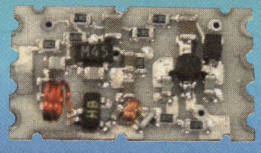

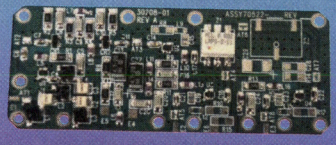

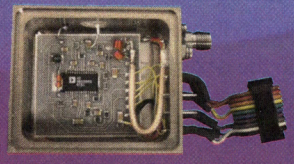

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Examine The Impact Of Frequency Dependence On Flicker-Noise Upconversion

THE TUNING CURVE of an inductive-capacitive (LC)-tuned voltage-controlled oscillator (VCO) changes from the ideal curve when a varactor with an abrupt C(V) characteristic is adopted and the full oscillator swing is used across the varactor. This curve relies on the oscillator bias current, reducing the practical tuning range, while the upconverted flicker noise of the bias current dominates the $1/f^3$ close-in phase noise, even when the waveform symmetry has been ensured. An approximation of the tuning curve for metal-oxide-semiconductor (MOS)-varactor-tuned VCOs yields a phase-noise model for double cross-coupled VCOs. The results are proved with a 0.25-µm complementary-MOS (CMOS) VCO for 5-GHz wireless-local-area-network (WLAN) receivers (Rxs). By removing the bias-current generator in a second oscillator, the close-in phase noise improves by 10 dB. See "Frequency Dependence on Bias Current in 5-GHz CMOS VCOs: Impact on Tuning Range and Flicker Noise Upconversion," *IEEE Journal Of Solid-State Circuits,* Vol. 37, No. 8, August 2002, pp. 1003-1011.

Analyze Fractal-Modulation Transmission Across Wireless Channels

TIME-VARYING CHANNELS ARE important to fractal-modulation systems because they represent the main configuration for communications systems that are based on fractal modulation. L. Atzori and D.D. Giusto of the IEEE, along with M. Murroni, compare fractal-modulation systems to quadrature-amplitude modulation (QAM) using a test-bed simulation environment where additive noise and fast fading are examined as error sources for transmission over wireless channels. Wavelet families for a fractal-modulation scheme are considered and performance for each on is measured. Results are presented that show the effectiveness of the fractal-modulation paradigm and confirm the effectiveness of its use in data broadcasting. See "Performance Analysis of Fractal Modulation Transmission Over Fast-Fading Wireless Channels," *IEEE Transactions On Broadcasting,* Vol. 48, No. 2, June 2002, pp. 103-110.

Consider Modern Digitizer-Testing Procedures

MODERN DIGITIZER-TESTING PROCEDURES usually consider a spectrally pure sine wave as the input signal due to the high performance of currently available sine-wave sources. The data sequence that is provided by the digitizer under test, when fed with a full-scale input, is then processed to calculate the quality parameters of this device under test (DUT). The accuracy of the approximated parameters depends upon the questions that are manifested in the employed test set up, as well as in the numerical-estimation procedure. Signal-processing algorithms must be used carefully as a method of ensuring the accuracy of all approximations. In his paper, IEEE member Dario Petri of the Italian Doctorate School in Instrumentation and Measurement provides a frequency-domain procedure for estimating the spectral performance of waveform digitizers. Its properties are analyzed and approximately unbiased estimators are proposed, along with expressions for their variances. Experimental results are presented to validate the analyses. The paper also includes directions and criteria that are useful for the design of the test procedure. See "Frequency Domain Testing of Waveform Digitizers," *IEEE Transactions On Instrumentation and Measurement,* Vol. 51, No. 3, June 2002, pp. 445-453.

Learn About An Antenna For Meteor-Burst Communications

THE 1930S INTRODUCED the concept of radio communications using meteor burst, where hordes of meteors found within the Earth's atmosphere provide ionized trails that reflect radio signals back to the planet, enabling communication to distances of 2000 km. The 1950s saw the first operational systems capable of using the meteor-burst concept, but it took the microprocessors and integrated circuits (ICs) of the 1970s to fully realize the potential of meteor-burst communications. In a paper, a mobile terminal antenna for communications in the very-high-frequency (VHF) band is proposed that satisfies the requirements for meteor-burst communications. These requirements include a 200-kHz bandwidth, a VSWR of 2:1.1 at the feed point, and horizontal polarization to minimize the Faraday rotation effects, as well as reducing the interference with military and land-mobile transmitters (Txs). See "Novel Mobile Terminal Antenna For Meteor Burst Communication Systems," *Microwave And Optical Technology Letters,* Vol. 34, No. 6, July 20, 2002, pp. 80-83.



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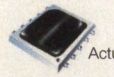
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MCA1-24LH	10	300-2400	6.5	40	6.45
MCA1-42LH	10	1000-4200	6.0	38	7.45
MCA1-60LH	10	1700-6000	6.3	30	8.45
MCA1-24MH	13	300-2400	6.1	40	6.95
MCA1-42MH	13	1000-4200	6.2	35	7.95
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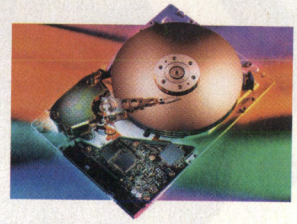



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DESIGN

Selecting Crystals For Stable Oscillators

Understanding how quartz-crystal resonators operate can lead to designing crystal oscillators with improved stability and better noise performance.

STEVEN BIBLE
Principal RF Applications Engineer
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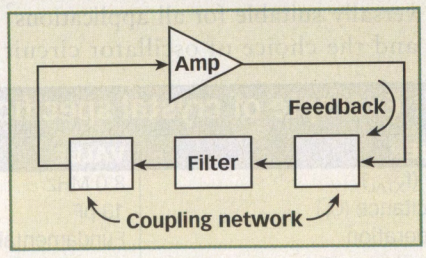
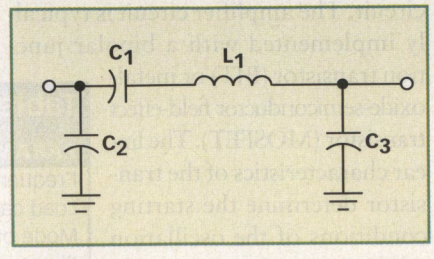
Oscillators are critical components in RF and digital designs. Although oscillator circuitry may already be provided as part of an integrated circuit (IC), a product-design engineer may still be required to select the crystal resonator and external capacitors. To achieve final product success, it is important that the designer has a basic understanding of how an oscillator and crystal function to select the correct crystal and external capacitors for the device. Poor crystal selection can lead to a product that does not operate properly, fails prematurely, or will not operate over the intended voltage and temperature range. What follows is a basic explanation of crystal resonators and crystal oscillators. Armed with this basic knowledge, a product design engineer will have the insight to select the correct crystal and external capacitors for an IC. Designers will also obtain an understanding of the interrelationships of the various circuits available that make up an oscillator circuit and what to consider when working with RF ICs and commercially available microcontrollers.

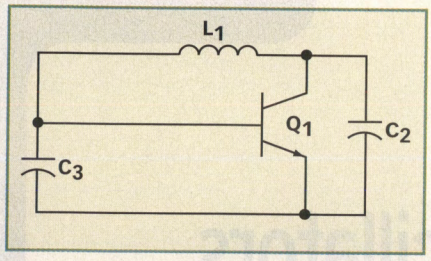
Reduced to its simplest components, a crystal oscillator consists of an amplifier and a filter operating in a positive feedback loop **(Fig. 1)**. To begin oscillation, the circuit must satisfy the following Barkhausen criteria: 1) the loop gain exceeds unity at the resonant frequency, and 2) the phase shift around the loop is $n2\pi$ radians (where n is an integer. Intuitively, it can be seen that the amplifier provides the gain for the first criteria. The amplifier is inverting, causing a π rad (180-deg.) phase shift to meet the requirements of the second criterion. The filter block provides an additional π rad phase shift for a total of 2-π rad (360 deg.) around the entire loop. By design, the filter block inherently provides the phase shift in addition to



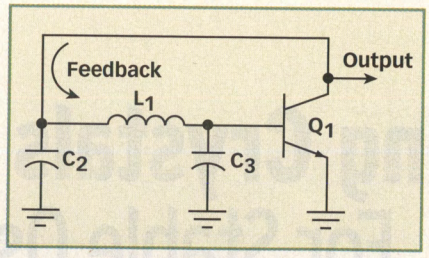
1. This block diagram offers a simplified representation of a crystal oscillator.



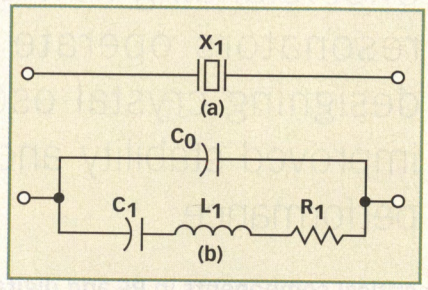
2. This diagram shows a basic LC series resonator.



3. This simplified oscillator circuit is designed without an RF ground.



4. This schematic diagram portrays the classic Pierce oscillator.



5. A crystal resonator can be represented by this equivalent circuit.

providing a coupling network to and from the amplifier. The filter block also sets the frequency of oscillation, using a tuned circuit (inductor and capacitor) or crystal.

Operation of an oscillator is generally broken up into two phases: start-up and steady-state operation. An oscillator must start itself with no external stimulus. When the power is first applied, voltage changes in the bias network result in voltage changes in the filter network. These voltage changes excite the natural frequency of the filter network and signal buildup begins and the signal developed in the filter network is small. Positive feedback and excess gain in the amplifier continuously increases the signal until the nonlinearity of the amplifier limits the loop gain to unity. At this point, the oscillator enters steady-state operation; the time from power on to steady-state operation is the oscillator start-up time.

An oscillator's steady-state operation is governed by the amplifier and the tuned circuit of the filter block. Loop gain steadies at unity due to the nonlinearity of the amplifier. The tuned circuit reactance will adjust itself to match the Barkhausen phase requirement of 2-π rads. During steady-state operation, the main concerns are the power output and loading of the tuned circuit. The amplifier circuit is typically implemented with a bipolar junction transistor (BJT) or metal-oxide-semiconductor field-effect transistor (MOSFET). The linear characteristics of the transistor determine the starting conditions of the oscillation while the nonlinear characteristics determine an oscillator's operating point.

The filter block sets the frequency that the oscillator will operate, which is accomplished by using an inductive-capacitive (LC) tuned circuit or crystal. **Figure 2** depicts a basic shunt-C coupled LC-series resonator that provides phase shift and a coupling network. Since an inverting amplifier is being used, the filter block must provide a μ-rad (180-deg.) phase shift to satisfy the second Barkhausen criteria. There is an unlimited number of circuit combinations for oscillators. Numerous circuits take on the name of their inventors (i.e., Butler, Clapp, Colpitts, Hartley, Meacham, Miller, Seiler, and Pierce) and, in turn, many of these circuits are derivatives of one another. Readers should not worry about a particular oscillator's nomenclature, but should focus on operating principles.[1] No one circuit is universally suitable for all applications[2] and the choice of oscillator circuit depends on device requirements.

The next step in developing a crystal oscillator is to add circuitry to the simplified oscillator block diagram shown in Fig. 1. **Figure 3** shows a simplified oscillator circuit drawn with only the RF components, no biasing resistors, and no ground connection. The inverting amplifier is implemented with a single transistor and the feedback mechanism depends upon which ground reference is chosen. Of the numerous oscillator types, the three most common ones are Pierce, Colpitts, and Clapp configurations, and each consists of common circuitry except that the RF ground points are at different locations. The type of oscillator commonly employed in ICs is the Pierce configuration **(Fig. 4)**. It has many desirable characteristics, including the capability of operating over a wide range of frequencies with very good short-term stability.[3] Although inductors and capacitors are convenient for use in oscillator-tuned circuits, the primary disadvantage of this type of oscillator is the tendency to drift with changes in temperature, power-supply voltage, or mechanical vibrations. Setting the frequency of an LC oscillator requires precise manual tuning.

Understanding Quartz

An understanding of how a quartz-crystal resonator works can provide design engineers with a better understanding of crystal oscillators. Quartz crystals have very desirable characteristics for use in tuned oscillator circuits, since their natural oscillation frequencies are very stable. In addition, the resonance has a very-high quality factor (Q), ranging from 10,000 to several hundred thousand. In some cases, Q values of two million are possible. Ultimately, however, Q values and stability are the principle limitations of crystal-based oscillators.

The practical frequency range for fundamental-mode AT-cut quartz crystals is 600 kHz to 30 MHz. Crystals for funda-

Table 1: Example of crystal specifications

PARAMETER	VALUE
Frequency (f_{XTAL})	8.0 MHz
Load capacitance (C_L)	13 pF
Mode of operation	Fundamental
Shunt capacitance (C_0)	7 pF (maximum)
Equivalent series resistance (ESR)	100 Ω (maximum)

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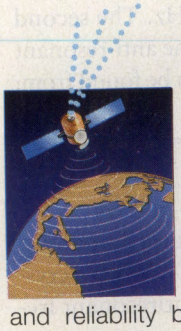

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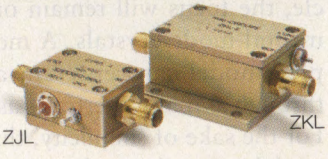
SPECIFICATIONS

Model	Freq (MHz)	Gain (typ) Midband (dB)	Gain (typ) Flat (±dB)	Max. P_{out}[1] (dBm)	Dynamic Range (Typ @2GHz[2]) NF(dB)	Dynamic Range (Typ @2GHz[2]) IP3(dBm)	I(mA)[3]	Price $ea. (1-9)
ZJL-5G	20-5000	9.0	±0.55	15.0	8.5	32.0	80	129.95
ZJL-7G	20-7000	10.0	±1.0	8.0	5.0	24.0	50	99.95
ZJL-4G	20-4000	12.4	±0.25	13.5	5.5	30.5	75	129.95
ZJL-6G	20-6000	13.0	±1.6	9.0	4.5	24.0	50	114.95
ZJL-4HG	20-4000	17.0	±1.5	15.0	4.5	30.5	75	129.95
ZJL-3G	20-3000	19.0	±2.2	8.0	3.8	22.0	45	114.95
ZKL-2R7	10-2700	24.0	±0.7	13.0	5.0	30.0	120	149.95
ZKL-2R5	10-2500	30.0	±1.5	15.0	5.0	31.0	120	149.95
ZKL-2	10-2000	33.5	±1.0	15.0	4.0	31.0	120	149.95
ZKL-1R5	10-1500	40.0	±1.2	15.0	3.0	31.0	115	149.95

NOTES:
1. Typical at 1dB compression.
2. ZKL dynamic range specified at 1GHz.
3. All units at 12V DC.



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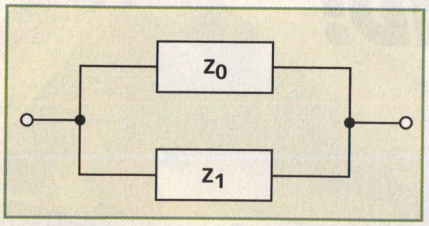


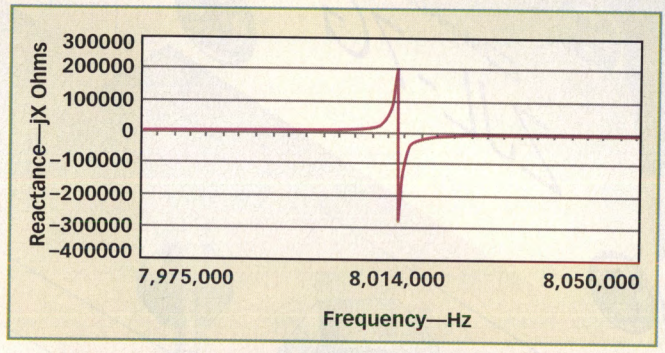
6. This crystal-equivalent circuit includes complex impedances.

mental frequencies higher than 30 to 40 MHz are very thin and fragile. Crystals are used at higher frequencies by operation at overtones of the fundamental frequency. Ninth-overtone crystals are used up to approximately 200 MHz, the practical upper limit of crystal oscillators. This article will limit its discussion to the use of fundamental-mode crystals.

Quartz is a piezoelectric material and when an electric field is placed upon it, a physical displacement occurs. Interestingly, an equivalent electrical circuit can be written to represent the mechanical properties of the crystal. The schematic symbol for a quartz crystal is shown in **Fig. 5a** and the equivalent circuit for a quartz crystal near fundamental resonance is shown in **Fig. 5b**. The equivalent circuit is an electrical representation of the quartz crystal's mechanical and electrical behavior and it does not represent actual circuit components. The crystal is, after all, a vibrating piece of quartz. The circuit elements C_1, L_1, and R_1 are known as the motional arm and represent the mechanical behavior of the crystal element, while capacitor C_0 represents the electrical behavior of the crystal element and holder.

The equivalent circuit in Fig. 5b represents one oscillation mode. For the types of crystal oscillators related to this article, the focus will remain on fundamental-mode crystals. A more complex model can represent a crystal through as many overtones as desired. For the sake of simplicity, this simple model is usually employed and different values are used to model fundamental or overtone modes. Spurious resonances occur at frequencies near the desired resonance. In a high-quality crystal, the motional resistance of spurious modes is at least two or three times the primary resonance resistance and the spurious modes may be ignored. In this model, C_1 represents motional arm capacitance (in Farads). It represents the elasticity of the quartz, the area of the electrodes on the face, and the thickness and shape of the quartz wafer. Values of C_1 are in the range of femtofarads (10^{-15} F or 10^{-3} pF).

L_1 represents motional arm inductance (in Henrys). It represents the vibrating mechanical mass of the quartz in motion. Low-frequency crystals have thicker and larger quartz wafers and range in a few Henrys. High-frequency crystals have thinner and smaller quartz wafers and range in a few megaHenrys. R_1 is the resistance (in Ω). It represents the real resistive losses within the crystal. Values range from 10 Ω for 20-MHz crystals to 200 kΩfor 1-kHz crystals. C_0 is the shunt capacitance (in Farads). It is the sum of capacitance due to the electrodes on the crystal plate plus stray capacitances due to the crystal holder and enclosure. Values of range from 3 to 7 pF.



7. This plot shows reactance as a function of frequency.

In selecting a crystal, a designer should be familiar with the electrical specifications found in a data sheet or catalog **(Table 1)**. When purchasing a crystal, the designer specifies a particular frequency, along with load capacitance and mode of operation. Notice that shunt capacitance C_0 is typically listed as a maximum value and not as an absolute value. Notice also that motional parameters C_1, L_1, and R_1 are not typically provided in the crystal data sheet. They can generally be obtained from a crystal manufacturer, or from measurements. **Table 2** shows equivalent-circuit values for an example crystal. In Table 2, shunt capacitance is provided as an absolute value. However, shunt capacitance can be measured with a capacitance meter at a frequency much less than the fundamental frequency.

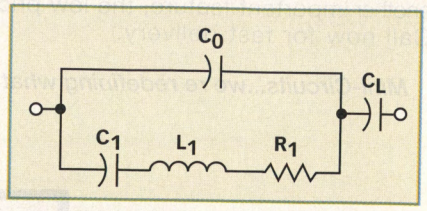
A crystal has two resonant frequencies characterized by a zero phase shift. The first is the series resonant frequency, f_s, which can be found from:

$$f_s = \frac{1}{2\pi\sqrt{L_1 C_1}} \qquad (1)$$

This is the basic equation for the resonant frequency of an inductor and capacitor in series. Recall that series resonance is that particular frequency which the inductive and capacitive reactances are equal and cancel: $X_{L1} = X_{C1}$. When the crystal is operating at its series resonant frequency the impedance will be at a minimum and current flow will be at a maximum. The reactance of the shunt capacitance, X_{C0}, is in parallel with the resistance R_1. At resonance, the value of $X_{C0} << R_1$ and, as a result, the crystal, appears resistive in the circuit at a value very near R_1. Solving for the example crystal, it can be found that f_s = 7,997,836.8 Hz. The second resonant frequency is the anti-resonant frequency, f_a, which can be found from:

$$f_a = \frac{1}{2\pi\sqrt{L_1 \times \frac{C_1 C_0}{C_1 + C_0}}} \qquad (2)$$

This equation combines the parallel capacitance of C_0 and C_1. When a crystal is operating at its antiresonant fre-



8. This equivalent circuit represents the load capacitance across a crystal.

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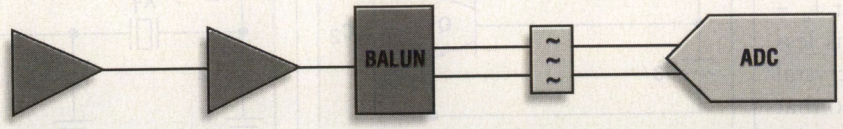



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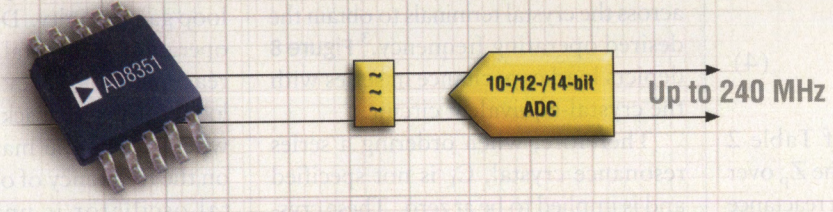

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quency, the impedance will be at its maximum and current flow will be at its minimum. Solving for the example crystal, it can be found that f_a = 8,013,816.5 Hz. Note that f_s is less than f_a and that the specified crystal frequency is between f_s and f_a so that $f_s < f_{XTAL} < f_a$. This area of frequencies between f_s and f_a is known as the "area of usual parallel resonance" or simply "parallel resonance." The crystal has resistance and reactance and therefore impedance. Figure 5b has been redrawn in **Fig. 6** to show the complex impedances of the equivalent circuit. The complex impedances[2] are defined as:

$$Z_0 = \frac{-j}{2\pi f C_0}$$

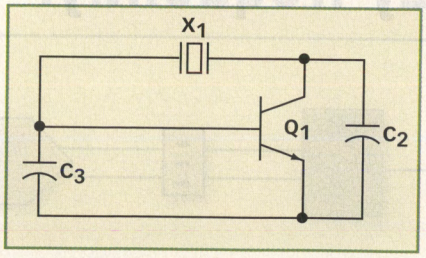
$$z_1 = R_1 + j\left(\frac{2\pi f L_1 - 1}{2\pi f C_1}\right) \quad (3)$$

Combining Z_0 and Z_1 in parallel yields:

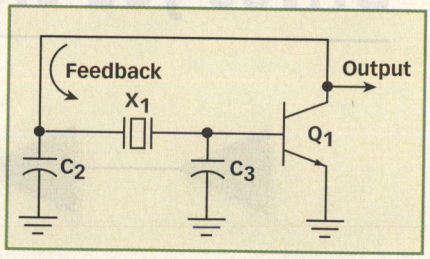
$$Z_p = \frac{Z_0 Z_1}{Z_0 + Z_1} \quad (4)$$

Plugging in the values of Table 2 into a spreadsheet program, the Z_p over frequency value is solved and a reactance verses frequency plot can be created **(Fig. 7)**. This plot shows where the crystal is inductive or capacitive in the circuit. Recall that positive reactances are inductive and negative reactances are capacitive. Between the frequencies f_s and f_a, the impedance of the crystal is inductive, and at frequencies less than f_s and frequencies greater than f_a the crystal is capacitive.

As mentioned earlier, the equivalent circuit shown in Fig. 5b is a simplified model that represents one oscillation mode. For this example it is the fundamental mode. The plot in Fig. 7 does not show overtone modes and spurious responses and, as a result, the crystal can appear inductive to the circuit at these overtone modes and spurious responses. Care must be taken in the selection of oscillator components, internal and external, to ensure the oscillator does not function at these points.



9. This simplified crystal-oscillator circuit has no RF ground.



10. This classic Pierce crystal oscillator includes feedback and output ports.

There is no difference in the construction of a series resonant crystal and a parallel resonant crystal, as they are manufactured exactly alike. The only difference between them is that the desired operating frequency of the parallel resonant crystal is set 100 PPM or so above the series resonant frequency. Parallel resonance means that a small capacitance, known as load capacitance (C_L), of 12 to 32 pF (depending on the crystal) should be placed across the crystal terminals to obtain the desired operating frequency.[3] **Figure 8** depicts load capacitance in series with the crystal-equivalent circuit.

Therefore, when ordering a series resonance crystal, C_L is not specified and is implied to be at zero. These crystals are expected to operate at in a circuit designed to take advantage of the crystals' mostly resistive nature at series resonance. On the other hand, a parallel resonant crystal has a specified load capacitance. This is the capacitive load the crystal expects to see in the circuit and thus operate at the specified frequency. If the load capacitance is something other than what the crystal was designed for, the operating frequency will be offset from the specified frequency.

A quartz crystal is a tuned circuit with a very-high Q, which, along with many other desirable attributes, makes the crystal an excellent component choice for oscillators. Crystal oscillators are recognizable from their LC oscillator counterparts.[1] For the Pierce oscillator, the crystal replaces the inductor in the corresponding LC-tuned circuit oscillators and not surprisingly, the crystal appears inductive in the circuit. Refer to the crystal's equivalent circuit in Fig. 5b when reviewing crystal-oscillator operation.

Upon startup, the amplitude of oscillation builds up to the point where nonlinearities in the amplifier decrease the loop gain to unity. During steady-state operation, the crystal, which has a large reactance-frequency slope (Fig. 7), is located in the feedback network at a point where it has the maximum influence on the frequency of oscillation. A crystal oscillator is unique in that the impedance of the crystal changes so rapidly with frequency that all other circuit components can be considered to be of constant reactance, this reactance being calculated at the nominal frequency of the crystal. The frequency of oscillation will adjust itself so that the crystal presents a reactance to the circuit, which will satisfy the Barkhausen phase requirement.[2]

Figure 9 represents a simplified oscillator circuit drawn with only the RF components, with no biasing resistors and no ground connection. In this design, the inductor has been replaced by a crystal. Looking at the Pierce crystal oscillator, the crystal will appear inductive in the circuit in order to oscillate. The Pierce crystal oscillator **(Fig. 10)**, which is designed to look into the lowest possible impedance across the crystal terminals,[3] oscillates just above the series resonant frequency of the crystal.

Table 2: Example of equivalent circuit crystal values

EQUIVALENT COMPONENT	VALUE
C_0	4.5 pF
C_1	0.018 pF
L_1	22 mH
R_1	30Ω

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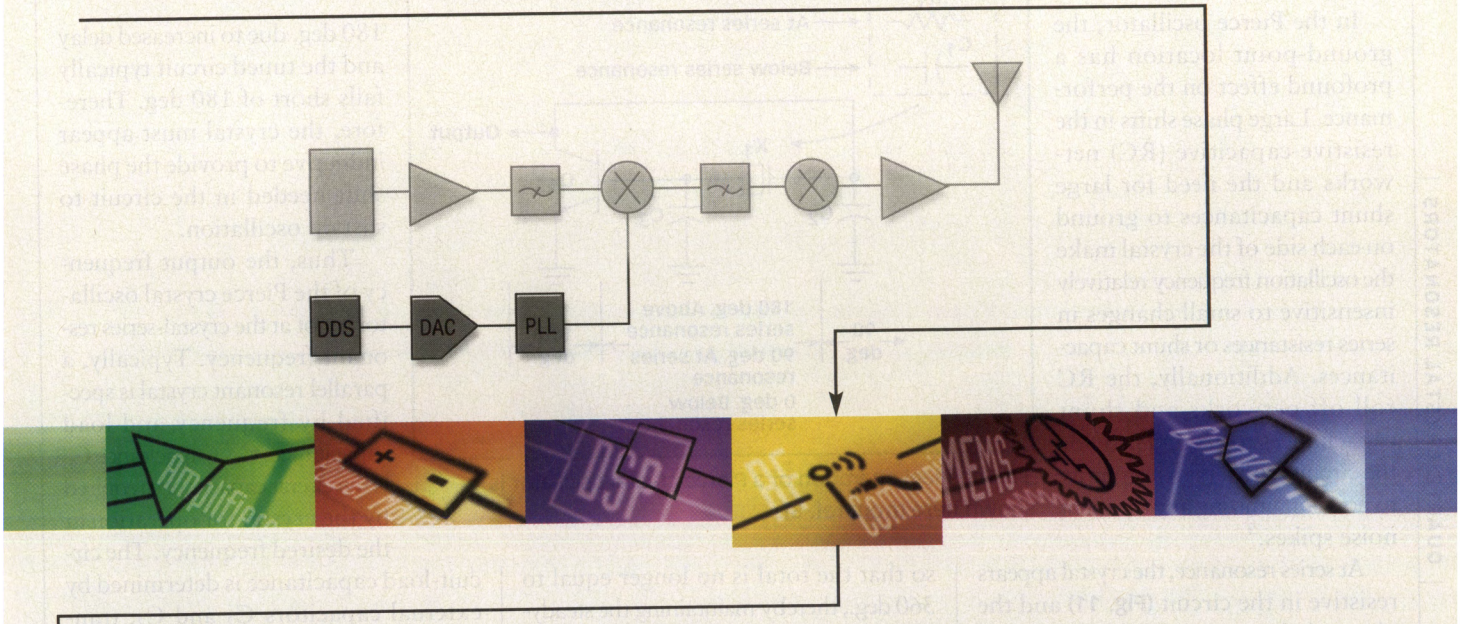

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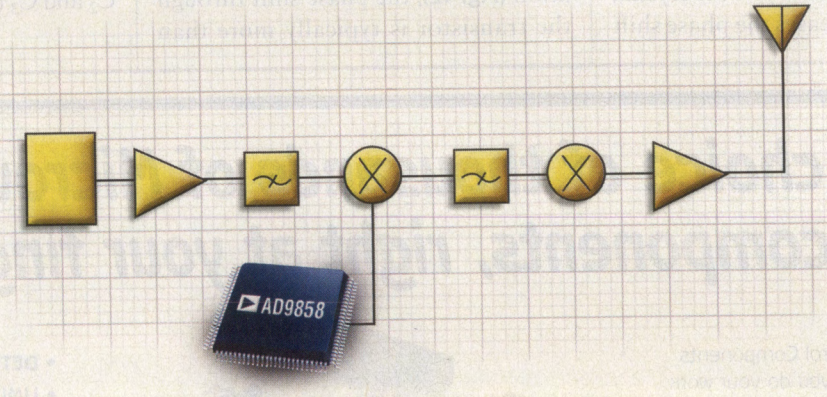

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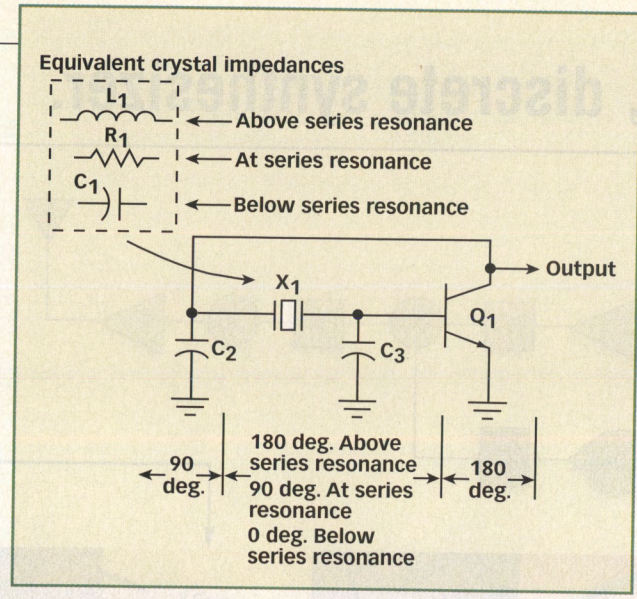

11. The ideal operation of a Pierce crystal oscillator is shown here (from ref. 3).

In the Pierce oscillator, the ground-point location has a profound effect on the performance. Large phase shifts in the resistive-capacitive (RC) networks and the need for large shunt capacitances to ground on each side of the crystal make the oscillation frequency relatively insensitive to small changes in series resistances or shunt capacitances. Additionally, the RC roll-off networks and shunt capacitances to ground provide the circuit with a high immunity to noise minimizing any transient noise spikes.[3]

At series resonance, the crystal appears resistive in the circuit **(Fig. 11)** and the phase shift around the circuit is 2-π radians (360 deg.). If the frequency of the circuit shifts above or below the series resonant frequency of the crystal, it increases or decreases the phase shift so that the total is no longer equal to 360 deg., thereby maintaining the steady-state operation at the crystal frequency. However, this only happens in an ideal circuit. Under actual circuit operation **(Fig. 12)**, the phase shift through the transistor is typically more than 180 deg. due to increased delay and the tuned circuit typically falls short of 180 deg. Therefore, the crystal must appear inductive to provide the phase shift needed in the circuit to sustain oscillation.

Thus, the output frequency of the Pierce crystal oscillator is not at the crystal-series resonant frequency. Typically, a parallel resonant crystal is specified by frequency and load capacitance, C_L. Capacitance C_L is the circuit capacitance required by the crystal for operation at the desired frequency. The circuit-load capacitance is determined by external capacitors C_2 and C_3, transistor internal capacitance, and stray capacitance, C_S. A product-design engineer can select the values of capacitors C_2 and C_3 to match the crystal C_L using:

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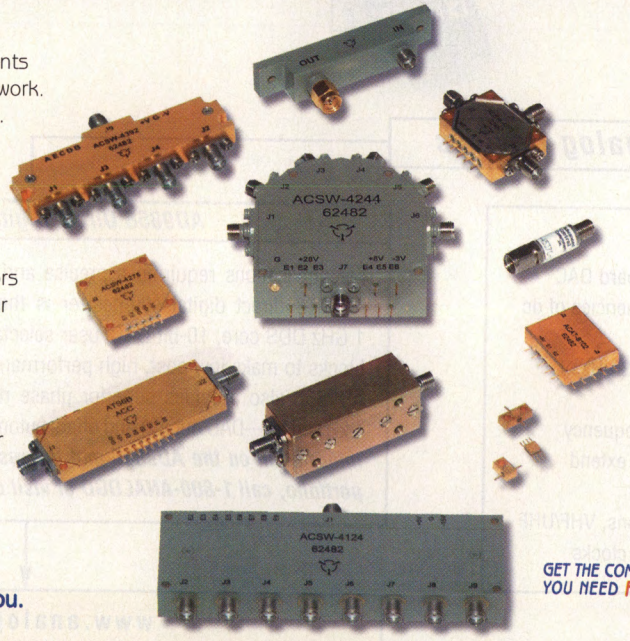

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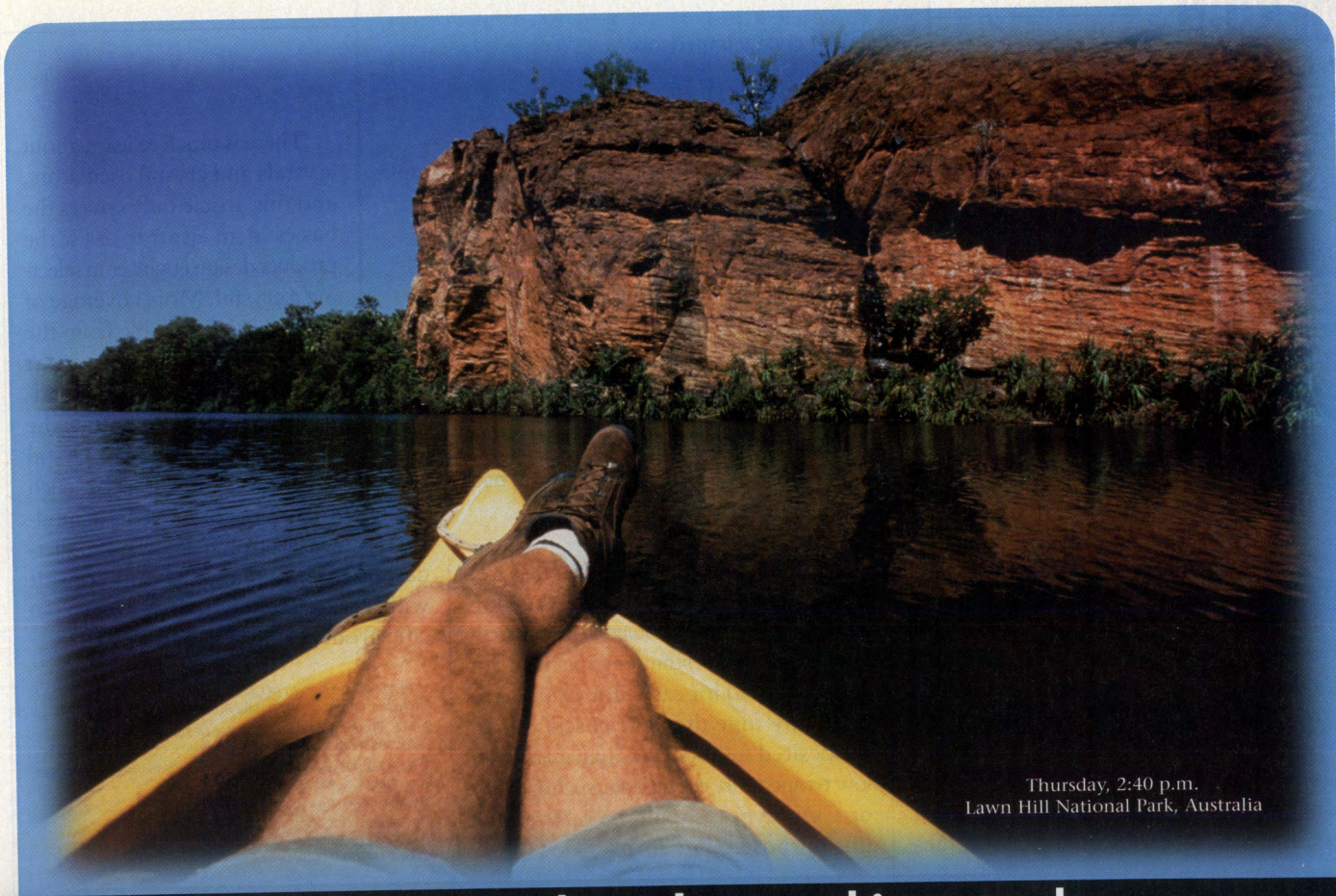

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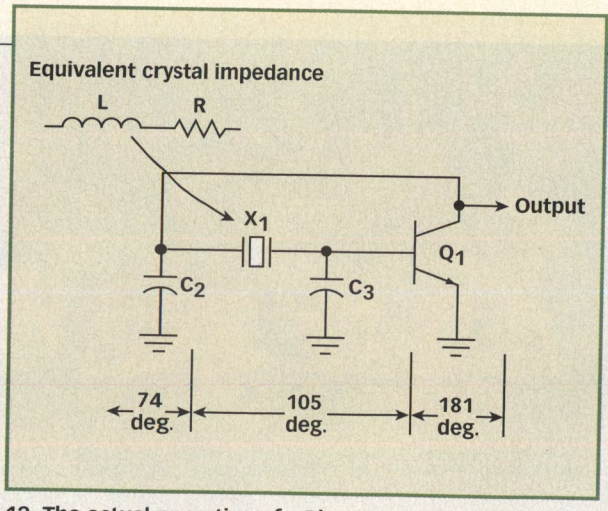
$$C_L = \frac{C_2 C_3}{C_2 + C_3} + C_S \qquad (5)$$

The printed-circuit-board (PCB) stray capacitance can be assumed to be in the range of 2 to 5 pF; it can be minimized by keeping circuit traces as short as possible. A desirable characteristic of the Pierce oscillator is the effects of stray reactances and biasing resistors appear across the capacitors C_2 and C_3 in the circuit rather than the crystal. If the circuit-load capacitance does not equal the crystal C_L, the operating frequency of the Pierce oscillator will not be at the specified crystal frequency. For example, if the crystal C_L is kept constant and the values of C_2 and C_3 are increased, the operating frequency approaches the crystal-series resonant frequency (i.e., the operating frequency of the oscillator decreases). Care should be used in selecting values of C_2 and C_3. Large values increase frequency stability but decrease the loop gain and may cause problems during oscillator startup. A trimmer capacitor can be substituted for capacitor C_2 or C_3 to manually tune the Pierce oscillator to the desired frequency. Capacitors with low temperature coefficients, such as NPO or COG types, should be selected for this purpose.



12. The actual operation of a Pierce crystal oscillator is shown here (from ref. 3).

There is much to learn about crystals and crystal oscillators, and this article only covers the basics in an effort to assist the product design engineer in selecting a crystal. More coverage of this topic is available from the Microchip website at www.microchip.com.[4] Readers are encouraged to study the design and operation of crystal oscillators because they are such important components in modern electronic designs. Product-design engineers should also consult with a crystal manufacturer about specific product design needs. MRF

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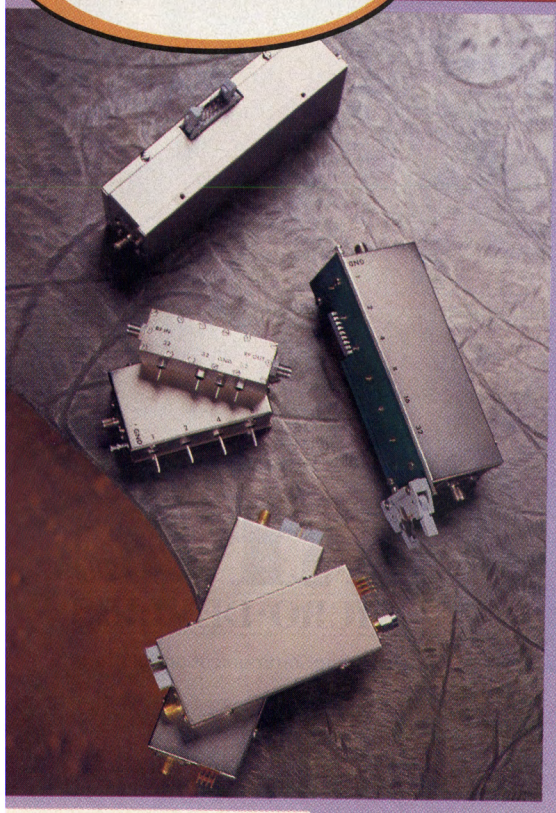

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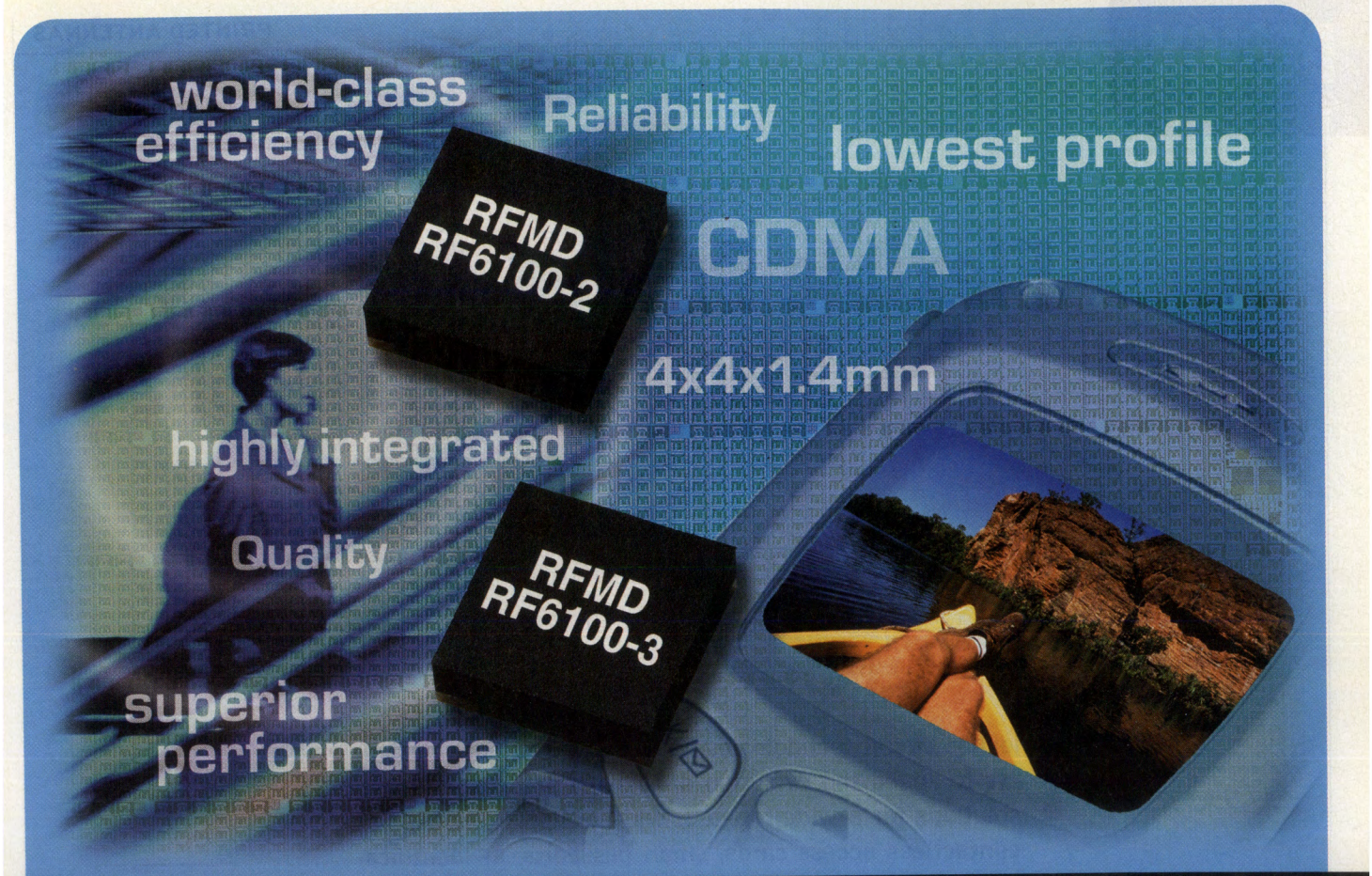

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Flexible Printed Antennas Span 100 kHz To 40 GHz

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Applications Engineer
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Flexible circuit technologies have enabled antenna designers to speed the evolution of versatile and cost-effective solutions for a wide range of wireless applications. From contactless access cards, smart passports, RF-identification (RFID) tags through Bluetooth devices, mobile telephone and pager antennas to point-to-point base-station antennas, designers have seized on flexible circuit technology to solve the problems of weight, shape, reproducibility, and cost. Antennas typically designed with a view to using a printed-circuit solution include flat coils, patches, microstrip antennas, stripline antennas, and dipoles with operating frequencies spanning the range from 100 kHz to 40 GHz. An example is illustrated in **the figure**. At the lower frequencies, smart cards and RFID tags predominate, while at the higher end, mobile radios (including telephones) and flat point-to-point antennas also use this approach.

Microstrip or patch antennas are widely used for microwave applications, as they are small and easily fabricated. Almost any shape of conductor can be excited on the surface of a dielectric substrate having a reference groundplane. Excitation can be through microstrip transmission line, from either the front or the back through an aperture in the groundplane. When microstrip antennas are produced on flexible circuit materials, including polyimide and polyester substrates (Table 1), dielectric constants from approximately 3 to past 5 at low frequencies typically characterize these materials (Table 2). This results in more energy being stored in the reactive near-field region, so the antennas are high quality factor (Q), narrowband compared to other types. However, the term "narrowband" in the gigahertz range still means a useful operating



This is an example of a typical flexible printed antenna for wireless applications.

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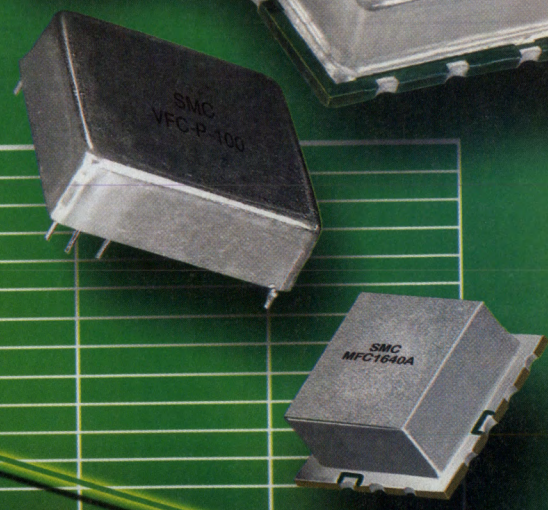

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bandwidth.

Narrower beamwidths, higher gain, and greater power handling can be achieved by combining multiple elements into arrays. Printed arrays will generally be of the "active" variety, where each element is individually driven by its own feed. Altering the phase shift between elements allows the antenna to be electronically steered without physically moving. Recent enhancements to this technology have lead to the development of spectrum- and power-efficient smart antennas which self-configure to direct the RF energy only where required. Similar to their thicker and heavier rigid counterparts, flexible circuits are available in a number of configurations, depending on the complexity of the conductor pattern to be implemented.

Single-sided antennas consist of a base-insulator film onto which one copper (Cu) conducting layer is bonded. The printed and etched pattern may be subsequently encapsulated with a further insulating film (coverlay) or printed mask (covercoat). Double-sided antennas consist of two Cu layers on either side of a central insulating film, allowing two layer-transmission lines to be easily implemented. If required by the design, the two layers can be interconnected by printing conductive silver (Ag)-loaded polymer ink through suitably positioned bleed holes. This construction lends itself to microstrip-antenna configurations.

Multilayer antennas consist of three or more Cu layers interconnected through plated-through-holes. Stripline transmission lines can also be included in the design. Sculptured antennas are a special variant of single-sided circuits, using a heavier-gauge Cu for the implementation of robust unsupported Cu termination features. Flex-Rigid designs combine standard multilayer hardboards with one or more of the flexible constructions outlined earlier. Typically, antenna designs are configured as single-sided circuits to support high volume reel-to-reel processing.

A number of materials are available depending on the antenna performance required and the nature of the assembly process. This selection deliberately excludes special high frequency/low-loss materials, which, in general, do not lend themselves to cost-effective volume manufacture. Table 1 shows readily available thicknesses, while the remainder of this section describes the

Table 1: Summarizing antenna materials

MATERIAL	USED FOR	THICKNESSES COMMONLY AVAILABLE
Copper	conductors	18, 35, 70, 105 µm
Polyimide	substrate	12, 25, 40, 50, 75, 100, 125 µm
Polyester	substrate	25, 50, 75, 125 µm
Epoxy glass	substrate	110 µm

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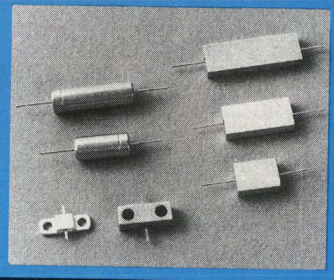



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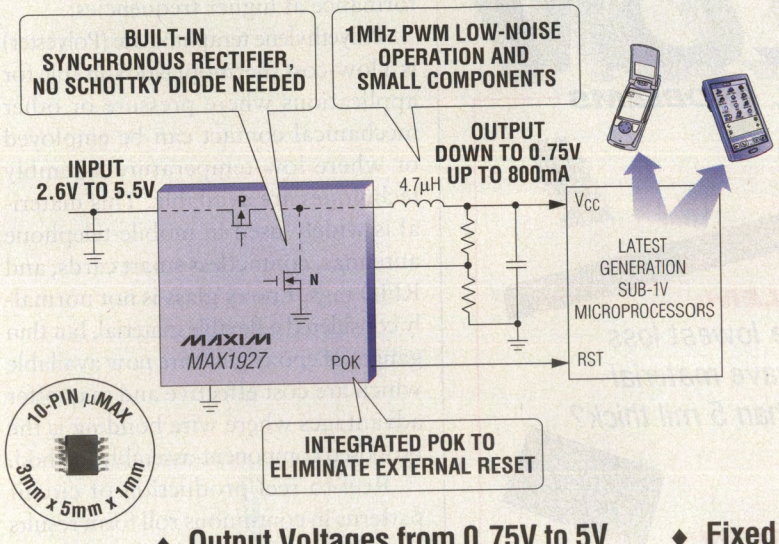

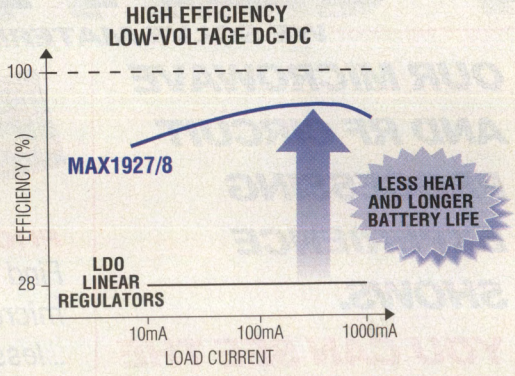

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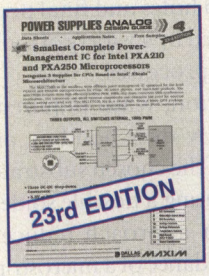

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Table 2: Summarizing dielectric properties

PROPERTY	POLYESTER	POLYIMIDE	EPOXY-GLASS
Dielectric constant, ϵ_r (1 kHz)	3.1	3.0	4.2 to 5.3
Dielectric constant, ϵ_r (1 MHz)	3.0	3.4	2.0 to 2.1
Dielectric constant, ϵ_r (1 GHz)	2.8	3.0	2.0 to 2.05
Loss factor, tan δ (1 MHz)	0.02	0.01	0.03
Dielectric strength, (V/mil)	3400	3600	240
Volume resistivity, (Ω-cm)	10^{18}	10^{18}	10^{15}

materials in more detail. Polyimide (standard and adhesiveless) is a high-temperature plastic which combines good dielectric properties with the ability to withstand all conventional assembly techniques. It is available with conventional Cu cladding where the metallization is bonded to the substrate with a separate acrylic or epoxy adhesive layer and in an adhesiveless form which provides superior dielectric performance at higher frequencies.

Polyethylene teraphthalate (Polyester) is a low-cost thermoplastic suitable for applications where pressure or other mechanical contact can be employed or where low-temperature assembly techniques are available. This material is widely used in mobile-telephone antennas, contactless smart cards, and RFID tags. Epoxy glass is not normally considered a flexible material, but thin gauges of epoxy glass are now available which are cost effective and may offer advantages where wire bonding is the proposed component-assembly method.

Reel-to-reel production of circuit patterns in continuous roll form results in consistent quality, while maintaining high-volume throughput. Some designs have added features such as local rigidizing, self-adhesive backing, or other added materials or components. Print-through Ag is an alternative technique to plated through-holes in high-volume double-sided circuits offering low-cost and rapid processing. Punching, drilling location holes, component attach holes and final profiling can be achieved by a variety of tooling or machining processes.

Surface insulation, when required, can be achieved by over bonding an additional layer of the chosen substrate material or by printing a flexible solder mask. The former approach reduces the calculated impedance of a microstrip by up to 20 percent, while the effect of the latter process is about 5 percent. The layout of the flexible circuit need not be limited to the antenna element itself. The technology supports a wide variety of assembly methods from mechanical crimping through wave, reflow, and hot-bar soldering. MRF

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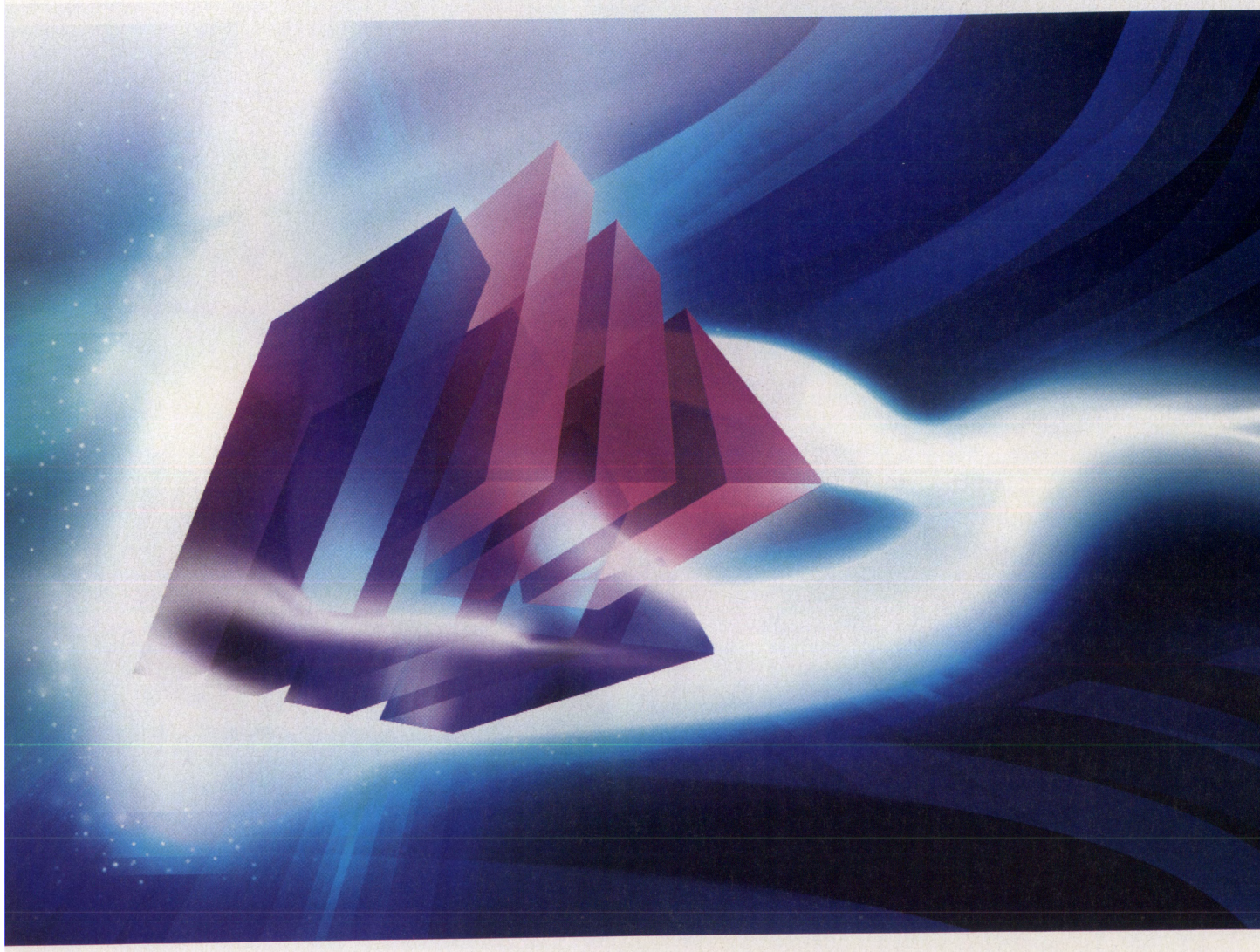

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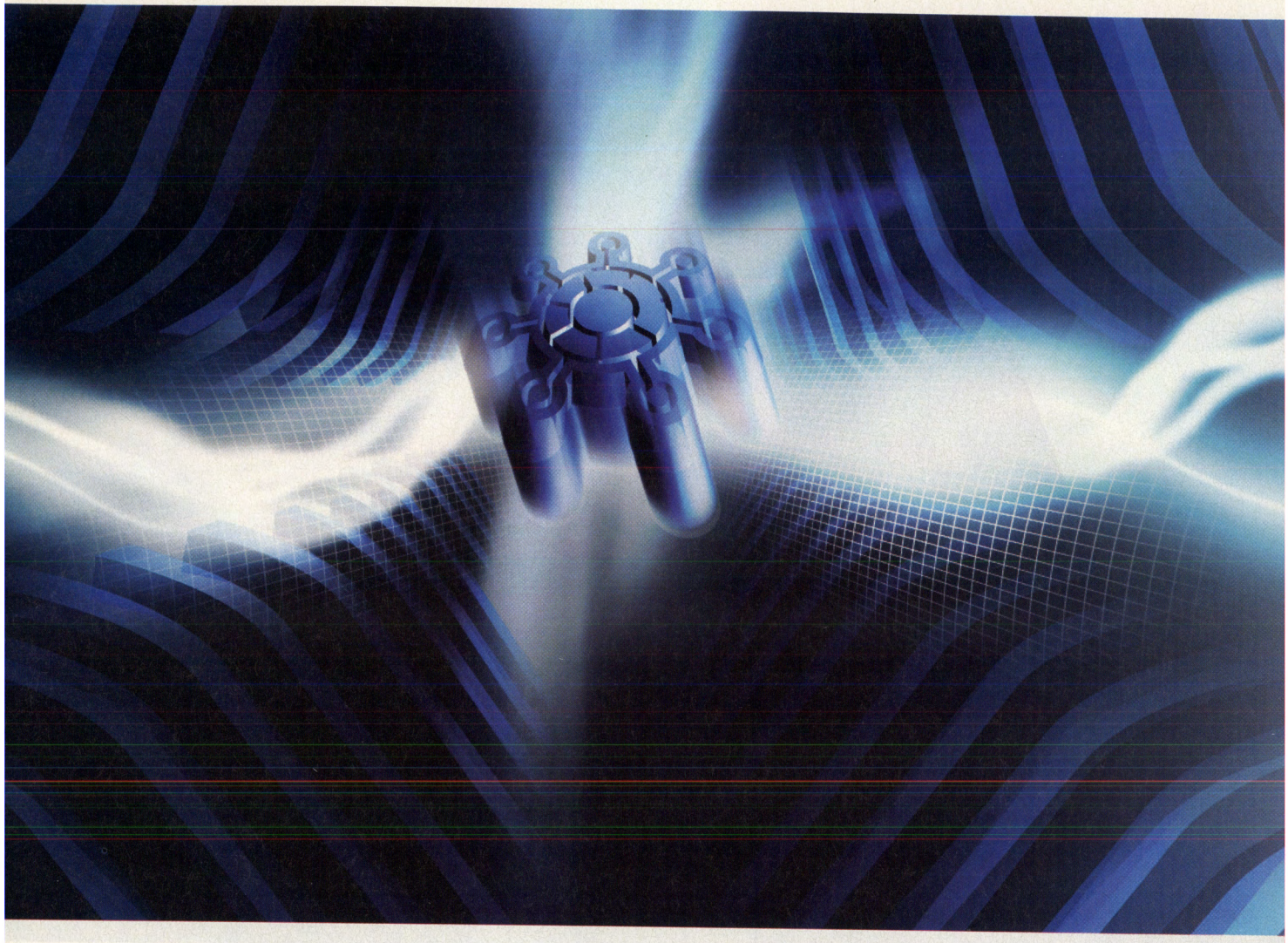

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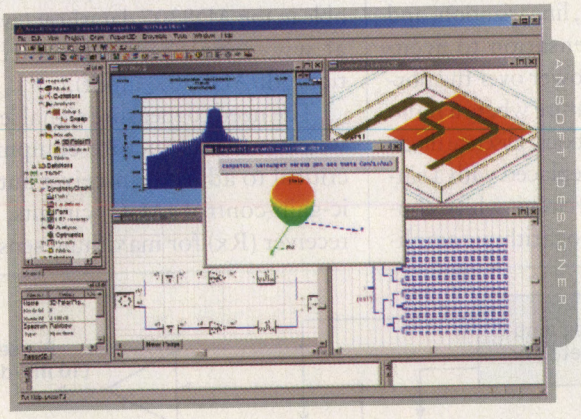

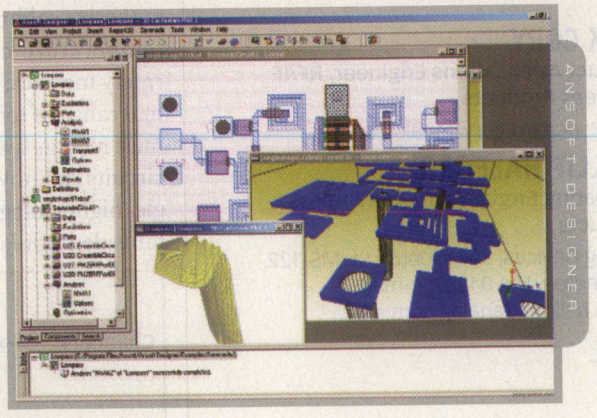

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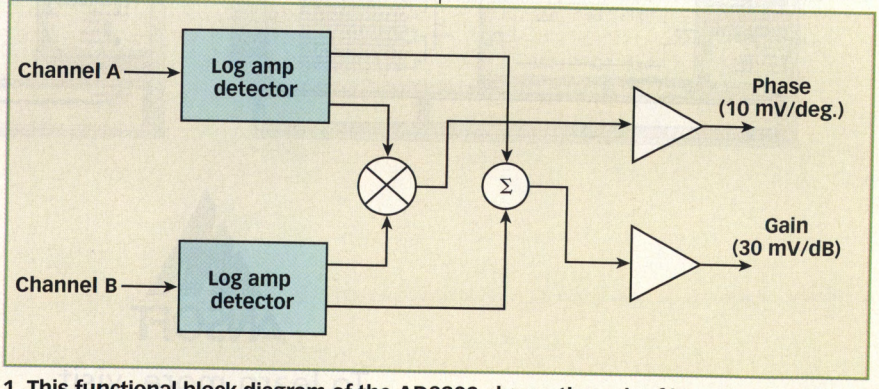
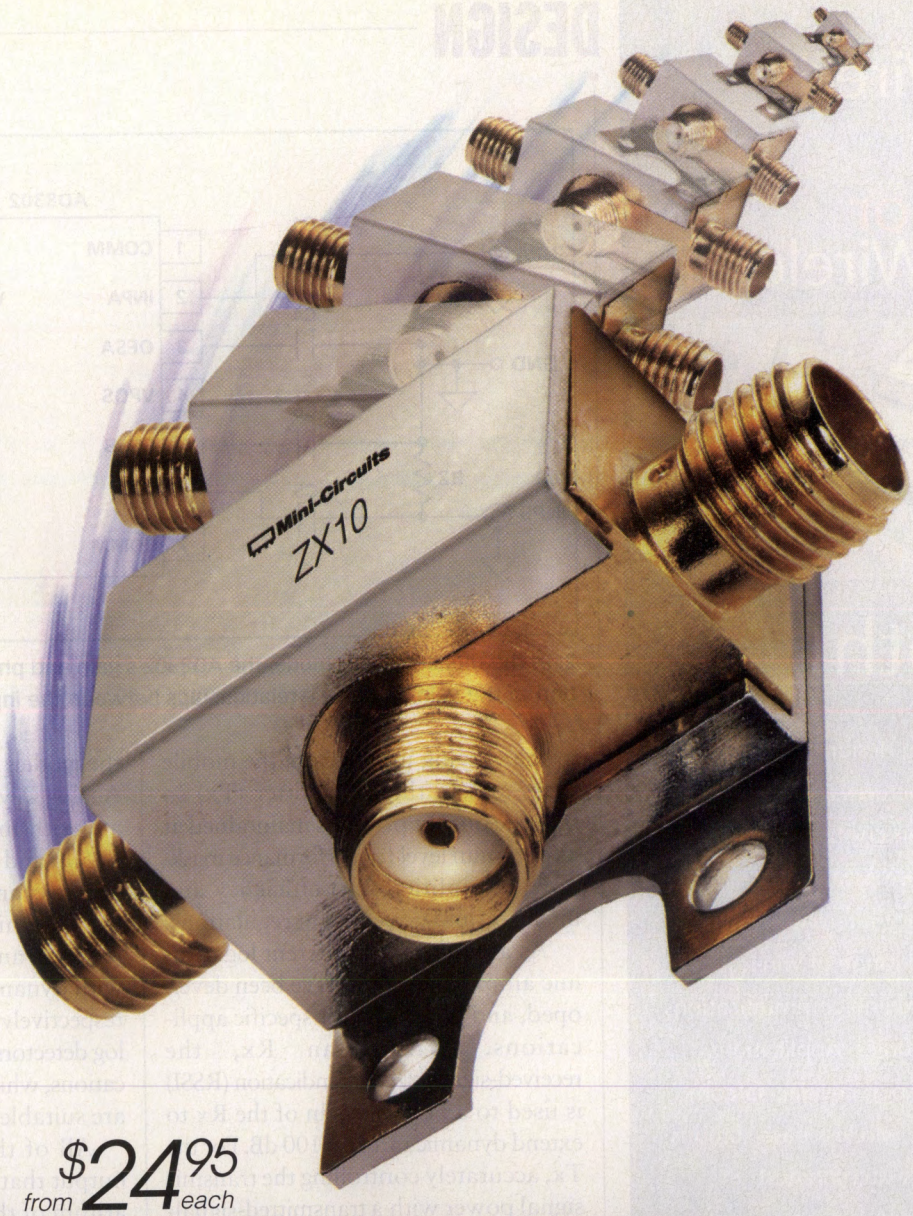
Measurements of gain and phase are vital to the operation of many radio systems. At one time, this capability required complex and expensive instruments or circuitry. Fortunately, now this capability can be incorporated into wireless infrastructure subassemblies through a compact, single-chip integrated circuit (IC) that enables the direct measurement and comparison of two independent RF or intermediate-frequency (IF) signals.

Circuits used to measure power levels are generally referred to as detectors. The most common form of detector is the diode, which typically requires extensive calibration, linearization, and temperature compensation to accurately measure RF power over the normal range of temperature where a radio must meet its specifications. Discrete diode circuits can now be replaced with a single, highly integrated circuit which contains demodulating logarithmic amplifiers, enabling the measurement of alternating RF signals over a wide dynamic range, into a continuously varying low-frequency output voltage that corresponds to the ratio of the magnitudes of the envelopes of the RF input signals. More detailed information on demodulation logarithmic amplifiers is available in the AD8307 datasheet (available at www.analog.com/productSelection/pdf/AD8307_a.pdf).

The need to measure signal levels in wireless infrastructure equipment is critical to adjust transceiver automatic-gain-control (AGC) circuits, in the receiver (Rx) for maximum sensitivity



1. This functional block diagram of the AD8302 shows the pair of logarithmic detectors integrated on a single chip.



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ZX10-2-25	1-2.5	20	1.2	26.95
ZX10-2-42	1.9-4.2	23	0.2	34.95
ZX10-2-71	2.95-7.1	23	0.25	34.95
ZX10-2-98	4.75-9.8	23	0.3	39.95
ZX10-2-126	7.4-12.6	23	0.3	39.95

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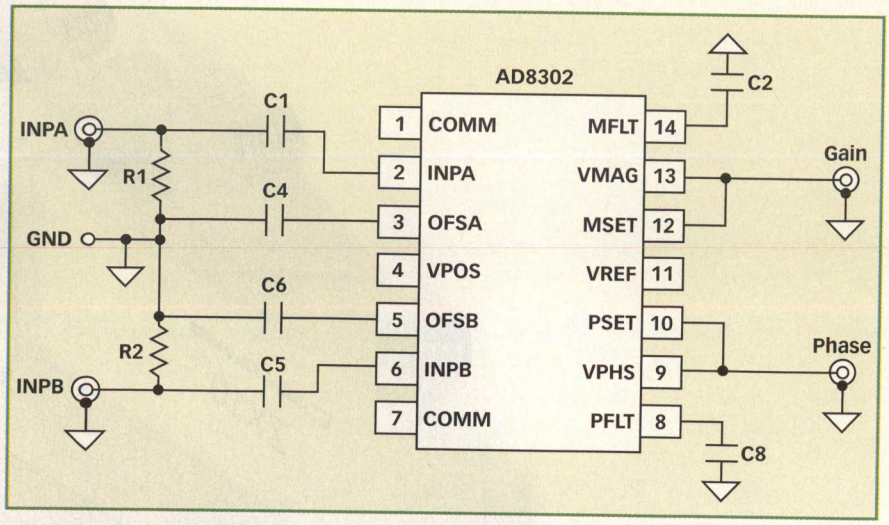
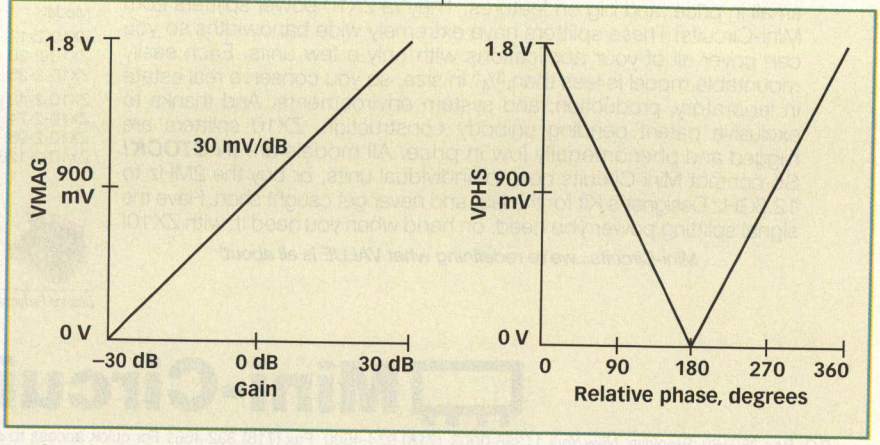


2. In the measurement mode, the AD8302's gain and phase outputs vary as a function of the gain and phase relationships between the input signals.

to the varying inputs from the mobile users and in the transmitter (Tx) so that the output power is maintained at its optimum level for performance mask, power-amplifier (PA) efficiency and linearity, and government regulations.

As a result many different logarithmic amplifier circuits have been developed, and optimized for specific applications. Within an Rx, the received-signal-strength indication (RSSI) is used to adjust the gain of the Rx to extend dynamic range to 100 dB. For the Tx, accurately controlling the transmit signal power with a transmitted-signal-strength indication (TSSI) at RF frequencies at the higher power levels significantly eases the implementation of controls for PA operating level for maximum efficiency. As a sampling of available power-detector/logamp circuits, the models AD8309 and AD8310 from Analog Devices (Wilmington, MA) operate with maximum input frequencies of 500 and 440 MHz, respectively and dynamic ranges of 100 and 95 dB, respectively, while the company's models AD8313 and 8314 operate to 2.5 GHz, with dynamic ranges of 70 and 45 dB, respectively. The AD8309 and AD8310 log detectors are designed for RSSI applications, while the AD8313 and AD8314 are suitable for TSSI applications.

All of these detectors provide an output that is proportional to the logarithm of the amplitude of the incoming signal. In many applications, it is necessary to detect and compare power levels at different points within the circuit so that adjustments for optimal performance can be made. Temperature drift causes changes in PA gain and



3. The AD8302 provides linear transfer functions for gain (left) and phase (right).

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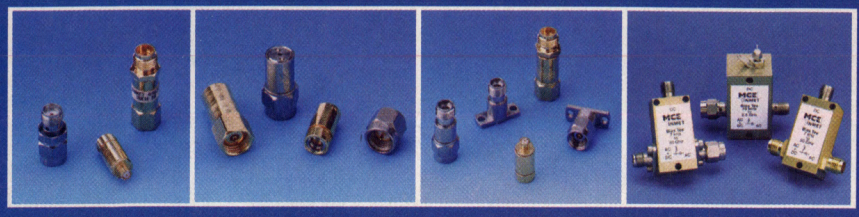

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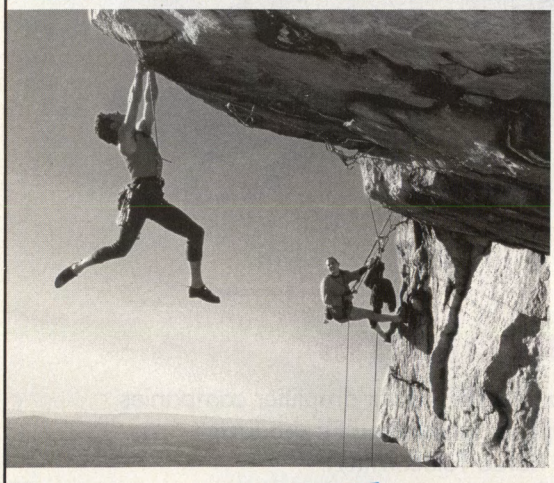

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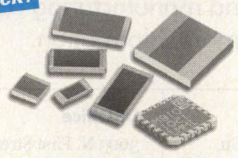

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every decibel of power must be preserved for maximum efficiency and minimum power consumption. To measure the differences between two input signals, a new circuit was developed as embodied by the company's model AD8302 Gain and Phase Detector. This function allows users to effectively calibrate their PA gain and radio-transceiver AGC chains by computing the gain or attenuation between the input and output of a system or subsystem.

The AD8302 integrates two identical logarithmic detectors on a single chip, each having dynamic range of 60 dB, a digital phase detector, and circuits used for amplitude and output scaling **(Fig. 1)**. With both logamps fabricated on the same die, their performance is matched very accurately as errors associated with each stage track each other, thereby effectively canceling each other. Two independent input signals, one of which might be a known reference signal, are applied to the Channel A and Channel B inputs. The outputs from the AD8302 are voltages proportional to the relative amplitude (i.e., gain or loss) and relative phase of the two input signals.

The AD8302 is the first integrated circuit (IC) to enable a direct ratio measurement between two independent RF input signals. The AD8302 enables designers to build accurate, low-cost system diagnostics and calibration into their final product.

A user can measure an amplitude difference range of up to 60 dB, which corresponds to input range from 0 to –60 dBm. Measurements at the center point at –30 dBm can be performed with exceptional accuracy. The phase measurement can be simultaneously measured over 180-deg. range. A full 360-deg. measurement range is possible when it is known *a priori* which channel leads or lags the other in phase.

The amplitude-signal output is scaled to 30 mV/dB and the phase output is scaled to 10 mV/deg. through on-chip output amplifier circuits. It is possible to adjust the scaling so that the user may, to a reasonable extent, customize these slopes. These output voltages may

be fed to an analog-to-digital converter (ADC) or they can be used to drive analog circuits.

The performance and accuracy of the AD8302 is dependent on a multitude of factors: the relative difference between the two input signals in amplitude and phase at the frequency of interest (RF or carrier frequency), the signal bandwidth at the carrier frequencies, and the device operating temperature. In characterizing the AD8302, the development team chose to provide accuracy and performance data over the popular cellular radio frequencies: 900 MHz, 1.8 GHz, and 2.2 GHz. However, the IC performs accurate amplitude measurement to 3 GHz and phase accuracy over a somewhat reduced range to 2.7 GHz. In addition, the AD8302 operates exceptionally well at low frequencies, so it is well-suited for baseband and IF and RF applications.

For gain measurement, the AD8302 offers excellent accuracy of better than 0.2-dB error beyond a 40-dB dynamic range at 900 MHz and better than 1 dB over a 60-dB dynamic range at 900 MHz. For phase measurements, the AD8302 offers better than 1-deg. error at 900 MHz over the full 0-to-180-deg. range. However, at the higher frequencies, the accuracy is reduced as 0- or 180-deg. relative phase is approached.

The AD8302 can measure the relative phase and magnitude of two input signals and operate in one of two modes: measurement or controller. In measurement mode, shown in **Fig. 2**, the gain and phase outputs are continuously variable as the corresponding relationships between the input signals are varied. The slope of the gain output is linear in decibels, at the rate of 30 mV/dB. The slope of the phase output is linear in degrees, and is nominally 10 mV/deg. These transfer functions are shown in **Fig. 3**. The measurement mode is enabled by connecting the VMAG output to the MSET pin for the magnitude measurement function, and by connecting the VPHS output to the PSET input pin for the phase-measurement function.

The gain-transfer function, avail-

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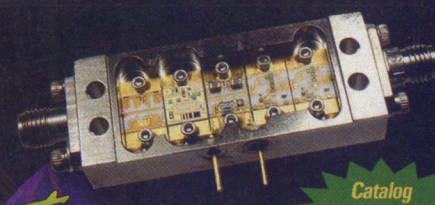

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Broadband Noise Figures

Catalog Amplifiers in 10 Days ARO

Model Number	Frequency Range (GHz)	Gain (dB min)	Flatness (±dB max)	Noise Figure (dB max)	P-1dB (dBm min)	IP3 (dBm) typ	DC Current (mA nom) +15 Vdc
AML218L4401	2.0 - 18.0	42	2	2.8	8	18	230
AML218L3402	2.0 - 18.0	34	2	3.0	14	24	240
AML218P3401	2.0 - 18.0	34	1.5	3.0	20	30	320
AML218P2504	2.0 - 18.0	25	1.5	3.0	22	32	330
AML618P3301	6.0 - 18.0	33	2	3.0	30	40	1040
AML818P3801	8.0 - 18.0	36	2.5	3.0	30	40	1100
AML1123P3001	11.0 - 23.0	30	2	4.0	19	29	240
AML0120L2401	0.1 - 20.0	25	1.5	3.0*	8	18	150
AML0120L3401	0.1 - 20.0	32	2	3.0*	8	18	195
AML0120L2403	0.1 - 20.0	24	1.5	3.0*	17	27	250
AML0123L2101	0.1 - 23.0	21	1.5	4.0*	8	18	170

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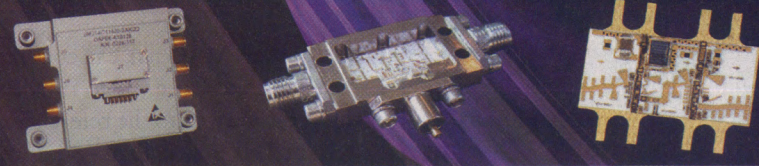

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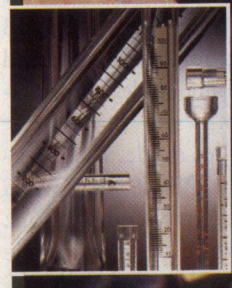

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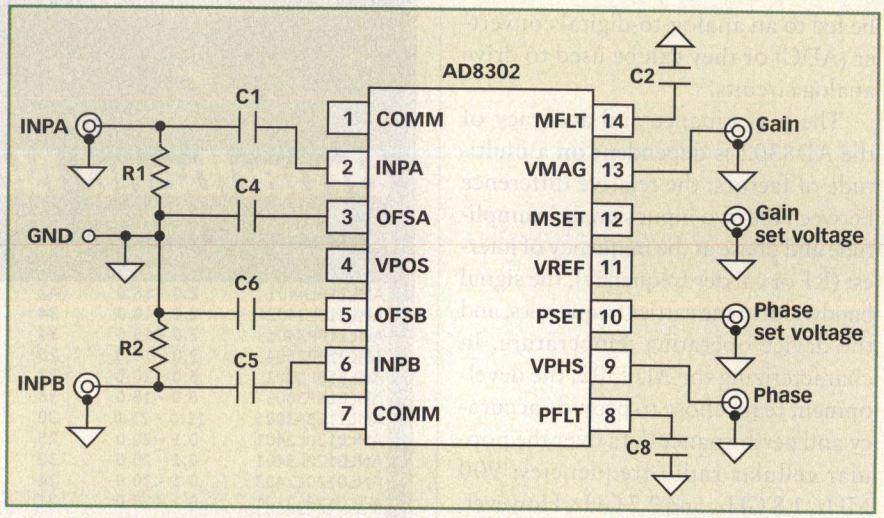

4. In the open-loop controller mode, the amplitude and phase outputs of the AD8302 are analogous to comparators.

able at the VMAG pin, can continuously measure gains from –30 to +30 dB when the input power to the reference channel, pin INPB, is held at –30 dBm. The phase-transfer function, available at pin VPHS, can unambiguously measure relative phase from 0 to 180 deg. If the total relative phase excursion exceeds 180 deg., then the VPHS output is less definitive, since the sign of the slope of the transfer function changes from negative to positive as relative phase passes through 180 deg. For the gain- and phase-measurement functions, optimal accuracy is obtained for mid-scale output voltages, i.e., 0-dB gain and 90-deg. relative phase, and for absolute signal amplitudes at approximately –30 dBm.

In the controller mode, the open-loop operation of the VPHS and VMAG outputs are analogous to comparators. This mode is enabled by breaking the external connections between VMAG and MSET, and VPHS and PSET, and applying control voltages to MSET and PSET that correspond to the conditions for which the AD8302 is testing. This configuration is shown in **Fig. 4**. For example, to set the AD8302 to indicate if gain is greater than or less than +10 dB, a reference voltage that corresponds to +10-dB gain (nominally +1.2 VDC) is applied to pin MSET. Then, if the magnitude of the signal applied to pin INPA is 10 dB (or more) larger than that of the signal applied to pin INPB, the voltage at pin VMAG will go to its most positive value, which is approximately +2 VDC. Otherwise, the voltage at pin VMAG will go to its minimum value, which is approximately 0 VDC. The controller mode for the phase-measurement output operates in a similar way. The voltage that corresponds to the condition for which the AD8302 tests is simply the same voltage that would be produced by the AD8302 in measurement mode when that condition is applied to the INPA and INPB inputs. The gain- and phase-measurement functions are independent of each other, so it is possible to operate one of these functions in measurement mode while operating the other in controller mode.

The AD8302 offers the ability to continuously measure the gain distribution or variation across a section of circuitry. Within a cellular base-station radio transceiver, ensuring that the AGC circuits in the Tx and Rx signals are adjusted to meet the needs of the cell-site capacity and compensated for drift over their operating temperature and lifetime are important considerations. The AD8302 can be set up as a monitor circuit continuously measuring the difference between signals, which can then be digitized, or set for alarm indication when used in the controller mode. The AGC or cell site can thus be dynamically

adjusted over the life of the base station.

Another key application for the AD8302 is to control the gain across a PA or to build simple linearization circuits **(Fig. 5)**. The AD8302 can be used in either mode in feedback and controller-based linearization architectures, as part of either active or passive circuitry within a PA system.

Cell-site operators are now deploying multicarrier PAs (MCPAs) that can handle multiple RF carriers simultaneously. An MCPA requires extensive linearization to remove intermodulation (IM) products. The AD8302 is suited to all forms of linearization architectures, including feedforward and predistortion. In a feedforward system, the AD8302 can be used to monitor the carrier cancellation within the first PA loop and distortion cancellation within the error-amplifier loop. The output response in both can be compensated within the gain and phase shifters.

Other key applications include adaptive antenna circuits where the dual matching of both log amplifiers eases the design in measuring the forward and reflective power or voltage standing-wave ratio (VSWR).

Along with a dual directional coupler and one or two attenuators, the AD8302 can be used to form a wideband VSWR/reflection-coefficient meter (figure not shown; contact author for details). The AD8302 compares the magnitude and phase of the incident signal, supplied by a generator, to that of the signal reflected from the load. For a perfect impedance match between the source, load, and transmission lines, the magnitude of the reflected signal would be 0 and the resultant SWR would be unity. As the impedance of any of these components is changed from this optimal value, the magnitude of the reflected signal will increase, increasing the SWR.

Since the AD8302 provides optimal accuracy when the magnitudes of the input signals are both –30 dBm, the coupling factors of the directional couplers and the attenuation factors of the attenuators are selected to provide these levels under nominal operating conditions. As a result, the AD8302 can accurately

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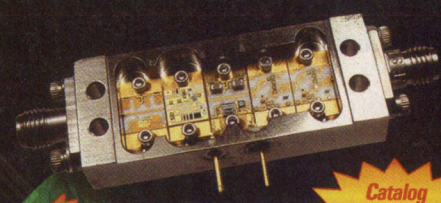

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Broadband Noise Figures

Catalog Amplifiers in 10 Days ARO

Model Number	Frequency Range (GHz)	Gain (dB min)	Flatness (±dB max)	Noise Figure (dB max)	P-1dB (dBm min)	IP3 (dBm) typ	DC Current (mA nom) +15 Vdc
AML001P1001	0.5 - 200MHz	10	0.5	5.5	30**	48	450
AMLTO1	0.1 - 1.0	15	0.5	1.5*	16	27	85
AMLTO2	0.1 - 2.0	14	0.5	1.5*	14	24	85
AMLTO3	0.5 - 2.0	15	0.5	0.9	9	18	65
AML012L3801	0.1 - 2.0	38	1	2.5	20	35	280
AML012P3801	0.1 - 2.0	35	1	2.7	26	36	450
AML0022P3601	0.02 - 2.5	36	0.75	3.8***	20	30	250
AML0016P0901	0.01 - 6.0	9	0.5	6.5*	25	36	320
AML0016P2001	0.01 - 6.0	20	1	3.2*	23*	36	480
AML0018P1001	0.01 - 8.0	10	0.75	5.2***	22*	31	170
AML016L1001	0.1 - 6.0	10	0.5	2.7	12	22	90
AML018L0901	0.1 - 8.0	9	0.5	2.0***	9	18	70
AML018P2001	0.1 - 8.0	20	1	4.0	20	30	240
AML0123L2101	0.1 - 23.0	21	1.5	4.0***	8	18	170

*Guaranteed from 200 MHz and up ** Guaranteed from 2MHz and up ***Guaranteed from 500 MHz and up Operational Voltage +12 Vdc

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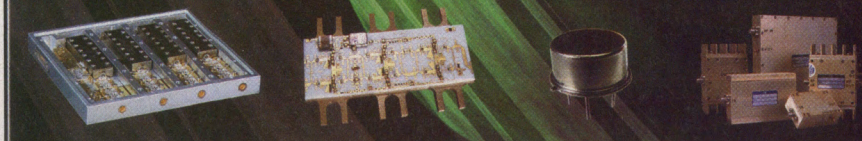

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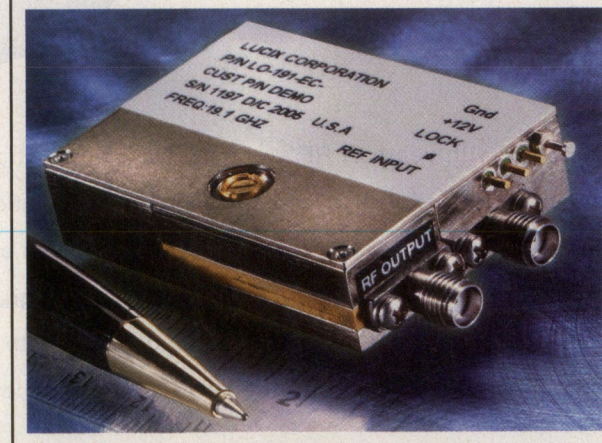

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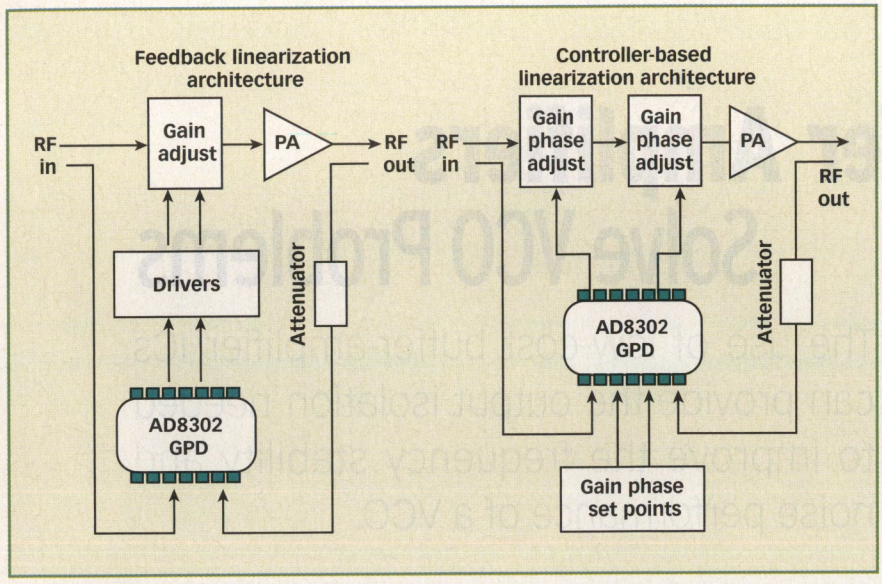

5. The AD8302 can be used in a variety of linearization configurations for minimizing IM products in multicarrier cellular PAs.

resolve variations in reflected signal magnitude of ±30 dB from the nominal conditions. The reflection coefficient, Λ, which is a vector quantity, is defined as:

Γ = reflected voltage/incident voltage = $(Z_L - Z_O) / (Z_L + Z_O)$

The SWR, in terms of the reflection coefficient, is:

$SWR = (1 + |\Gamma|) / (1-|\Gamma|)$

If one arbitrarily selects the coupling factors of both directional couplers to be 20 dB, then the attenuation factors of the attenuators are selected as follows. The attenuator that drives pin INPB, $ATTEN_B$, is selected to ensure that the signal level at the termination resistor R_B is –30 dBm under nominal conditions. Then, the attenuation factor of the other attenuator, $ATTEN_A$, is selected to also deliver –30 dBm to pin INPA under nominal conditions. If one assumes that the return loss of the load is nominally 20 dB, then the reflected signal from the load coupled towards pin INPB is 20 dB lower than the incident signal amplitude, so the value of $ATTEN_B$ that would deliver –30 dBm to pin INPB is 20 dB smaller than the value selected for $ATTEN_A$. For example, if $ATTEN_B$ is selected to be 23 dB and the nominal return loss of the load is 20 dB, then $ATTEN_A$ should be 23 – 20 = 3 dB. The measured reflection coefficient can be used to calculate the level of impedance mismatch or SWR of a particular load condition. This configuration proves particularly useful in diagnosing varying load impedances within antenna systems.

In a test instrument such as a vector-network analyzer (VNA), the AD8302 can be configured to measure the reflection coefficient of a device under test (DUT) to determine the complex impedance of the DUT.

The AD8302 is fabricated with a high-performance silicon (Si) bipolar-process transistors with cutoff frequencies to 25 GHz. The device, which is packaged in a 14-lead thin-shrink, small-outline package (TSSOP), is specified over the –40 to +85°C temperature range. The AD8302 has a power-measurement range of –60 to 0 dBm to 3 GHz. It has a gain-measurement range of 60 dB (0 to +1.8 VDC) and phase-measurement range of 180 deg. (0 to +1.8 VDC). The amplitude accuracy is better than 0.2 dB across the 60-dB range and the phase accuracy is better than 1 deg. across the 180-deg. range. The small-signal envelope bandwidth is 30 MHz. The device typically consumes 19-mA current from a supply voltage of +2.7 to +5.5 VDC. MRF

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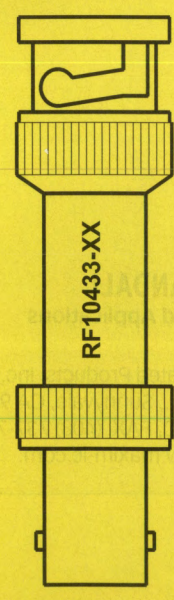

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Isolation between two circuit stages is often achieved by introducing a buffer amplifier between them. This isolation minimizes adverse effects in a wide range of applications, and especially for those using RF signals. Poor output isolation can produce various mechanisms that disturb oscillator performance, so a buffer stage is often included at oscillator outputs. In discussing these uses for buffer amplifiers, this article focuses on a voltage-controlled oscillator (VCO) whose active device is an NPN bipolar transistor. The resulting applications generally operate with other active devices as well.

Before discussing the addition of a buffer-amplifier stage, consider some typical VCO characteristics and how isolation problems can degrade performance. A common problem, for example, is the frequency change exhibited by a VCO in response to varying load conditions (frequency pulling). A change in impedance seen by the VCO output can induce changes in the DC voltages across junctions of the VCO's active device. A change in the collector-to-base voltage (V_{cb}) of a bipolar device, for instance, affects the collector-to-base capacitance (C_{cb}), which in turn can alter the oscillation frequency by affecting the overall tank resonance **(Fig. 1)**.

Another frequency-pulling phenomenon is sometimes referred to as injection locking or injection pulling. It concerns the effect of an interfering signal that is very near the VCO's operating frequency. When an interferer's amplitude at the VCO output port is sufficient, it can cause the VCO to shift its oscillation frequency to match the interfering frequency.[1] Another key performance factor affected by poor output isolation is phase noise. Much research has been done in the last few years to better describe the generation of phase noise in oscillators. Conditions that produce phase noise include changes in load impedance, power reflections back to the VCO output, excessive ground current, and radiated coupling due to poor RF layout. The induced voltage changes can cause bias-current fluctuations in the active device, a modulating effect on C_{cb}, perturbations in amplitude, and other subtle problems that degrade performance.[2]

Typical MAX2472 S-parameters

Frequency (MHz)	900	1900
S_{11} (mag, phase)	0.68786, –21.6	0.529663, –44.1
S_{21} (mag, phase)	1.764006, –80.4	1.592209, –117.6
S_{12} (mag, phase)	0.005821, 137.5	0.031189, 173.4
S_{22} (mag, phase)	0.810028, –29.4	0.776247, –61.6

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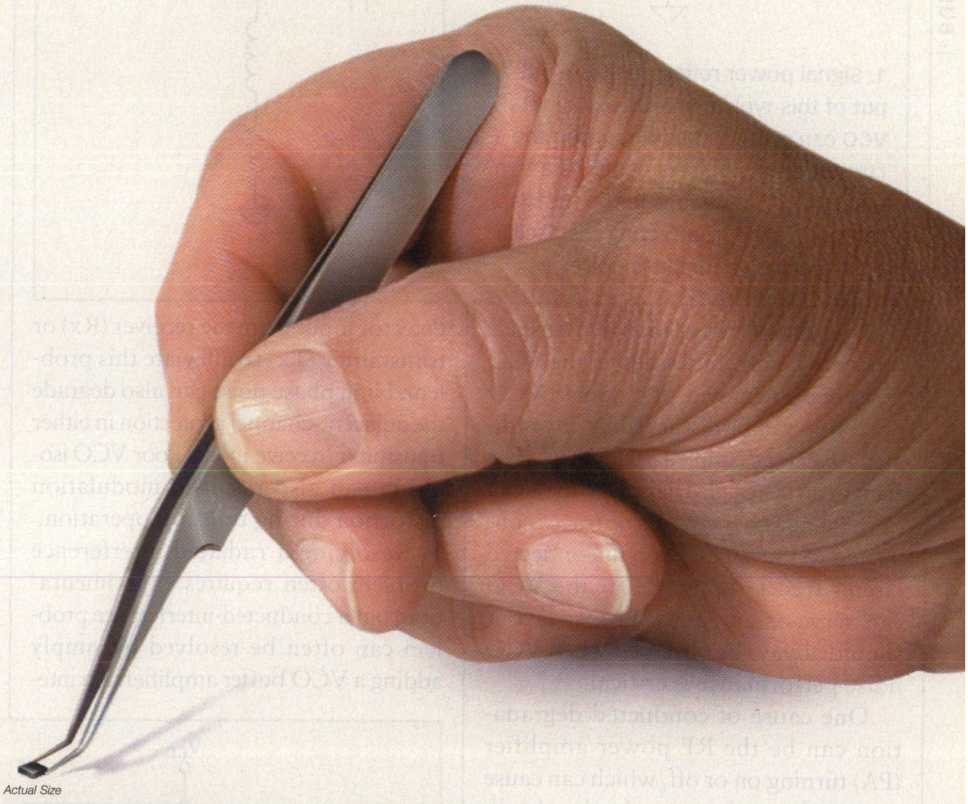
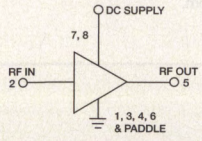


Actual Size

Biasing Configuration



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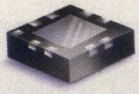

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MNA-3	0.5-2.5	5.0 2.8	16.2 15.2	11.4 9.7	1.60
MNA-4	0.5-2.5	5.0 2.8	16.6 14.6	17.0 13.4	1.90
MNA-5	0.5-2.5	5.0 2.8	22.8 21.4	12.2 10.1	1.60
MNA-6	0.5-2.5	5.0 2.8	23.5 21.5	18.0 14.1	2.25
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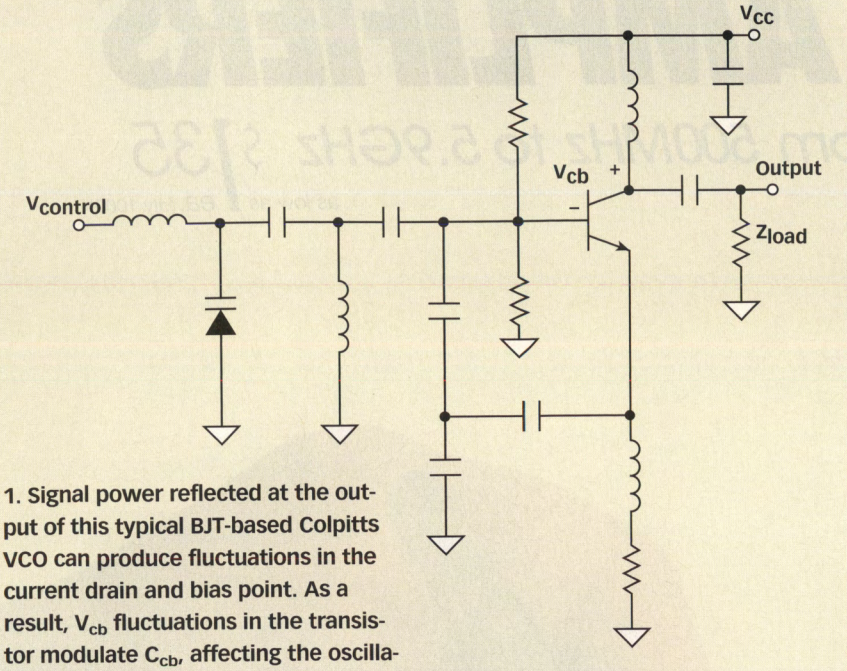


1. Signal power reflected at the output of this typical BJT-based Colpitts VCO can produce fluctuations in the current drain and bias point. As a result, V_{cb} fluctuations in the transistor modulate C_{cb}, affecting the oscillator frequency and phase noise.

Adequate VCO isolation also depends on board layout, and whether the VCO is discrete, integrated, or modular. VCO operation can be disturbed by any radiated RF energy coupled to the VCO. The energy can be coupled directly to the VCO or through other circuits or traces connected to the VCO. Even unconnected circuit traces running near the VCO can serve as antennas. Proper layout should always be observed when VCO noise performance is critical.

One cause of conducted degradation can be the RF power amplifier (PA) turning on or off, which can cause an impedance change in the signal path or in other circuits, thereby picking up radiated RF energy and conducting it back through the signal path. Good printed-circuit-board (PCB) layout helps to minimize radiated and conducted perturbations of the VCO. Grounding, shielding, and the routing of traces near the VCO can affect VCO operation, as well as the amount of isolation the VCO buffer circuit can achieve.

It is also important to understand how these degradation mechanisms manifest themselves during radio operation. Poor output isolation can degrade the phase-locked-loop (PLL) lock time when a reflected signal reaches the VCO. It may be necessary to isolate the phase-detector input from the receiver (Rx) or transmitter (Tx) to alleviate this problem. High phase noise can also degrade the adjacent-channel protection in either transmit or receive mode. Poor VCO isolation can also result in modulation distortion during transmit operation.

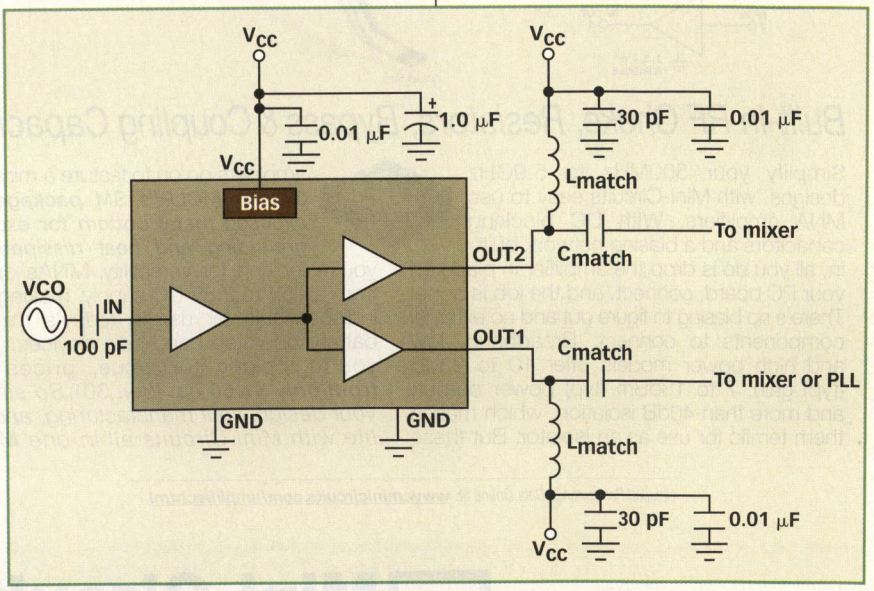
Resolving a radiated-interference problem often requires experimentation, but a conducted-interference problem can often be resolved by simply adding a VCO buffer amplifier. An integrated buffer such as the MAX2472 is small and provides excellent isolation of the VCO. Its circuit topology is suitable for providing the local oscillator (LO) and phase-detector input signals, while maintaining isolation between them and the VCO. Analysis of the scattering (S)-parameters in the **table**[3] show that the MAX2472 can improve poor VCO output isolation **(Fig. 2)**. The typical isolation achieved between VCO and mixer is approximately 44 dB at 900 MHz and 30 dB at 1900 MHz. The device provides highly stable gains at those frequencies, of 10 and 8 dB, respectively.

The MAX2473 integrated-circuit (IC) amplifier makes a good VCO buffer when there is only one signal path at the VCO output. As an added feature, its adjustable bias current minimizes current drain in portable applications.

Some VCO isolation problems require extensive analysis, and others are easily overcome. Small, integrated VCO buffers such as the MAX2472/MAX2473 can provide the simple solutions for VCO problems. MRF

REFERENCES

1. B. Razavi, *RF Microelectronics*, Prentice-Hall, Englewood Cliffs, NJ, 1998, pp. 225-226.
2. T.H. Lee and A. Hajimiri, "Oscillator Phase Noise: A Tutorial," *IEEE Journal of Solid-State Circuits*, Vol. 35, March 2000.
3. MAX2472/MAX2473 datasheet, Maxim Integrated Products, Sunnyvale, CA. The latest version is available at www.maxim-ic.com.



2. At 900 MHz, this IC buffer amplifier (a model MAX2472) provides approximately 10-dB gain and 44-dB isolation between the VCO and the mixer.

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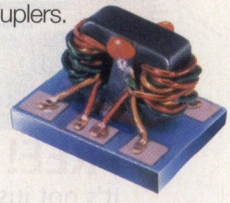

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10dB	DBTC-10-4-75	5-1000	1.4	20
12dB	DBTC-12-4	5-1000	0.7	21
13dB	DBTC-13-4	5-1000	0.7	18
13dB	DBTC-13-5-75	5-1000	1.0	19
		1000-1500	1.4	17
16dB	DBTC-16-5-75	5-1000	1.0	21
		1000-1500	1.3	19
17dB	DBTC-17-5	50-1000	0.9	20
		1000-1500	1.0	20
		1500-2000	1.1	14
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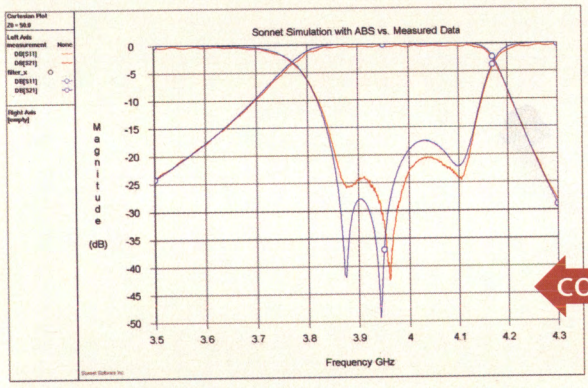
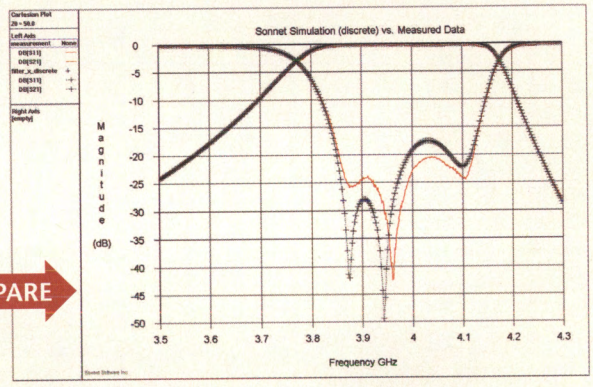
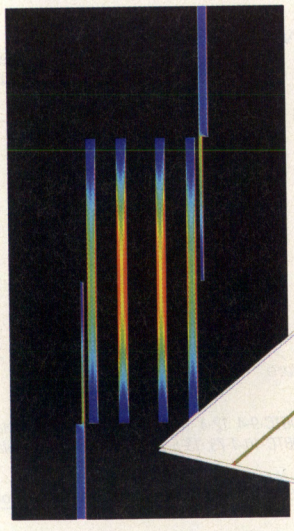


ABS simulation data based on 4 discrete EM analysis frequencies and measured data

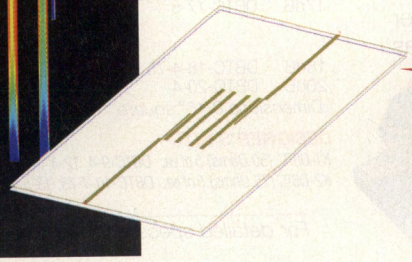
COMPARE



300-point Discrete EM analysis and measured data



Current density computed by Sonnet 8.0. Smoothly varying current density along with edge current singularities are evidence of highly accurate EM simulation results.



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Modeling 802.11a-Based WLAN Systems

Complex communications standards such as the OFDM-based IEEE 802.11a methods employed in WLANs can be simulated with the right system-level software simulation tools.

Multicarrier modulation schemes are gaining momentum in the communications marketplace due to bandwidth efficiency. In particular, orthogonal-frequency-division-multiplex (OFDM) systems allow carriers to be very tightly packed by maintaining strict orthogonality between the various signals across the band. Efficient digital-signal-processing (DSP) implementations of the required signal processing are making this modulation type fast and cost-effective for use in consumer systems. This complex modulation scheme does present some design challenges, however. Fortunately, modern simulation tools can be used to solve some of these design challenges.

DR. KURT MATHIS
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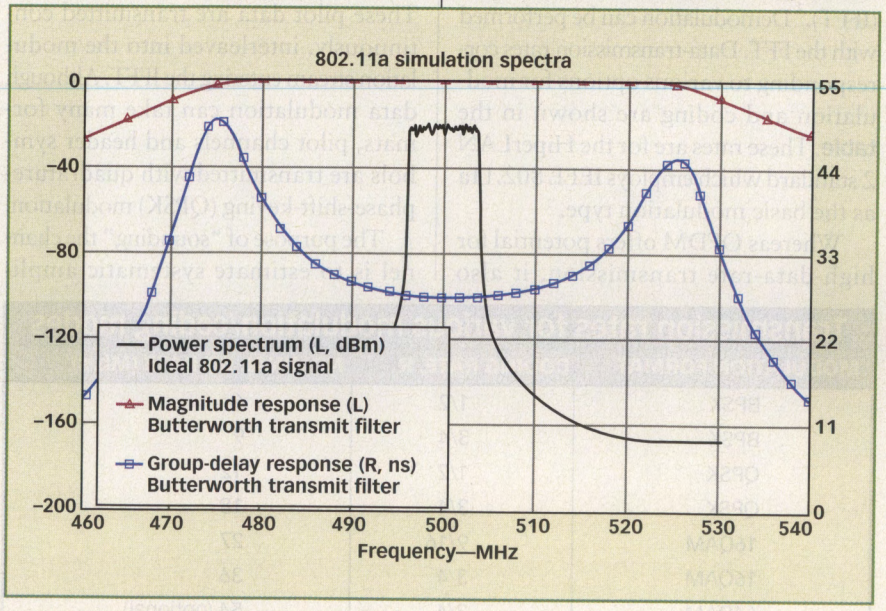
Frequency-domain multiplexing using orthogonal carriers was first proposed by Chang.[1] Many independent data channels could be packed into a surprisingly small bandwidth. Orthogonality prevents the carriers from interfering with each other, thus obviating the need for guard bands. Although this technique promised great improvements in effective transmission rates, its cost



1. Spectral characteristics of an IEEE 802.11a WLAN system are shown here.

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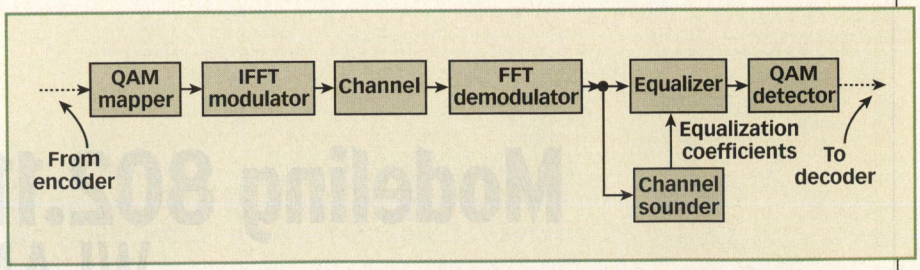
and size limited OFDM to military applications for many years. One of the first OFDM modems was designed for military high-frequency (HF) radios.[2] Recently, advances in electronic components and hardware have enabled this and other communications technology, such as code-division multiple access (CDMA), to enter the commercial world.

OFDM is something of a misnomer, since the transmission technique is often employed to spread a single data stream over a band of carriers, with substreams transmitted in parallel. The IEEE 802.11a data transmission standard is designed to carry packetized data over parallel channels at information rates approaching 12 b/s/Hz. The spectrum of an IEEE 802.11a signal is shown in the center of **Fig. 1**. In IEEE 802.11a wireless-local-area-network (WLAN) systems, 12 carriers at the ends of the spectrum are left "unloaded" to produce a power-spectral density with a steep decline at the band edges.

The high rate efficiencies associated with IEEE 802.11a are made possible through the use of high-order modulation schemes being applied to the individual carriers. Quadrature-amplitude modulation (QAM) of various levels is applied to each carrier. The modulation is normally applied to 64 carriers simultaneously with a computationally efficient Inverse Fast Fourier Transform (IFFT).[3] Demodulation can be performed with the FFT. Data-transmission rates corresponding to various options for modulation and coding are shown in the **table**. These rates are for the HiperLAN 2 standard which employs IEEE 802.11a as the basic modulation type.

Whereas OFDM offers potential for high-data-rate transmission, it also requires additional signal processing for synchronization and other auxiliary receiver (Rx) functions. Some disadvantages of OFDM include susceptability to oscillator phase noise and sensitivity to transmission amplitude/phase distortion. The following section will briefly explore this latter issue.



2. This block diagram shows a simplified IEEE 802.11a WLAN system simulation.

In an IEEE 802.11a system, data is transmitted in frames, with each frame containing a header which is used for synchronization and control. Although the full description of the header is beyond the scope of this article, suffice it to say that the header contains a correlation word for detection of the start of the frame and also an embedded pilot sequence used for "sounding" the amplitude/phase variation across the wideband OFDM channel.

The 64 carriers correspond to 48 data channels, 12 unloaded guard channels, and 4 pilot channels. The pilot channels are equally spaced across the OFDM bandwidth, providing the capability to equalize in separate sub-bands. These pilot data are transmitted continuously, interleaved into the modulation stream entering the IFFT. Although data modulation can take many formats, pilot channels and header symbols are transmitted with quadrature-phase-shift-keying (QPSK) modulation.

The purpose of "sounding" the channel is to estimate systematic amplitude/phase variations across the OFDM bandwidth. Since IEEE 802.11a systems have such a large bandwidth, even a small amount of linear distortion imposed upon the signal can cause the various channels to be misaligned in amplitude/phase. This can wreak havoc on the detection process, since in-phase (I) and quadrature (Q) outputs from all channels are serialized and overlaid in the QAM scatter diagram. It is for this reason that equalization becomes critically important for 802.11a-based systems. **Figure 2** illustrates a simplified block diagram of an IEEE 802.11a system simulation employing equalization.[4] As mentioned earlier, amplitude/phase distortion can present problems in the demodulation/detection process. This distortion can occur over the environmental transmission channel.

This type of distortion can also occur even in various filters placed within the transmission chain by the system designers. Furthermore, filter characteristics can change with time or may not be known before a signal is received (e.g., the precise characteristics of a transmit filter are not known to the Rx). For this reason, equalization requires that the overall transmission channel frequency characteristics be measured and corrected on a dynamic basis. Fortunately, frequency-domain equalization is relatively simple and is efficiently implemented in OFDM systems. The purpose of the sounder in Fig. 2 is to use the known sounding or training sequence to estimate the variation in amplitude/phase in the various channels. The result of this operation is a vector of complex numbers, or coefficients, that represent the estimated amplitude/phase for each channel. These estimates can be used by a simple equalizer, which only performs a channel-by-channel complex mul-

Transmission rates for various modulation/coding modes

MODULATION FORMAT	CODING RATE, R	NOMINAL BIT RATE (Mb/s)
BPSK	1/2	6
BPSK	3/4	9
QPSK	1/2	12
QPSK	3/4	18
16QAM	9/16	27
16QAM	3/4	36
64QAM	3/4	54 (optional)

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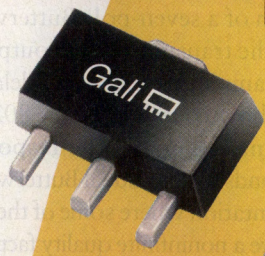

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Gali 1	DC-8000	12.7	11.8	±0.5	12.2	4.5	27	108	40	3.4	.99
Gali 21	DC-8000	14.3	13.1	±0.6	12.6	4.0	27	128	40	3.5	.99
Gali 2	DC-8000	16.2	14.8	±0.7	12.9	4.6	27	101	40	3.5	.99
Gali 33	DC-4000	19.3	17.5	±0.9	13.4	3.9	28	110	40	4.3	.99
Gali 3	DC-3000	22.4	19.1	±1.7	12.5	3.5	25	127	35	3.3	.99
• Gali 6F	DC-4000	12.1	11.6	±0.3	15.8	4.5	35.5	93	50	4.8	1.29
• Gali 4F	DC-4000	14.3	13.4	±0.5	15.3	4.0	32	93	50	4.4	1.29
• Gali 51F	DC-4000	18.0	15.9	±1.0	15.9	3.5	32	78	50	4.4	1.29
• Gali 5F	DC-4000	20.4	17.4	±1.5	15.7	3.5	31.5	103	50	4.3	1.29
• Gali 55	DC-4000	21.9	18.5	±1.7	15.0	3.3	28.5	100	50	4.3	1.29
• Gali 52	DC-2000	22.9	17.8	±2.5	15.5	2.7	32	85	50	4.4	1.29
• Gali S66	DC-3000	22	17.3	±2.4	2.8	2.7	18	136	16	3.5	.99
Gali 6	DC-4000	12.2	11.8	±0.3	18.2	4.5	35.5	93	70	5.0	1.49
Gali 4	DC-4000	14.4	13.5	±0.5	17.5	4.0	34	93	65	4.6	1.49
Gali 51	DC-4000	18.1	16.1	±1.0	18.0	3.5	35	78	65	4.5	1.49
Gali 5	DC-4000	20.6	17.5	±1.6	18.0	3.5	35	103	65	4.4	1.49

■ Low frequency cutoff determined by external coupling capacitors. † Measured in test fixture P/N 90-6-20-26.
▲ Models tested at 2GHz except Gali 4, 5, 6, 51, 52, 6F, 4F, 51F, 5F at 1GHz.
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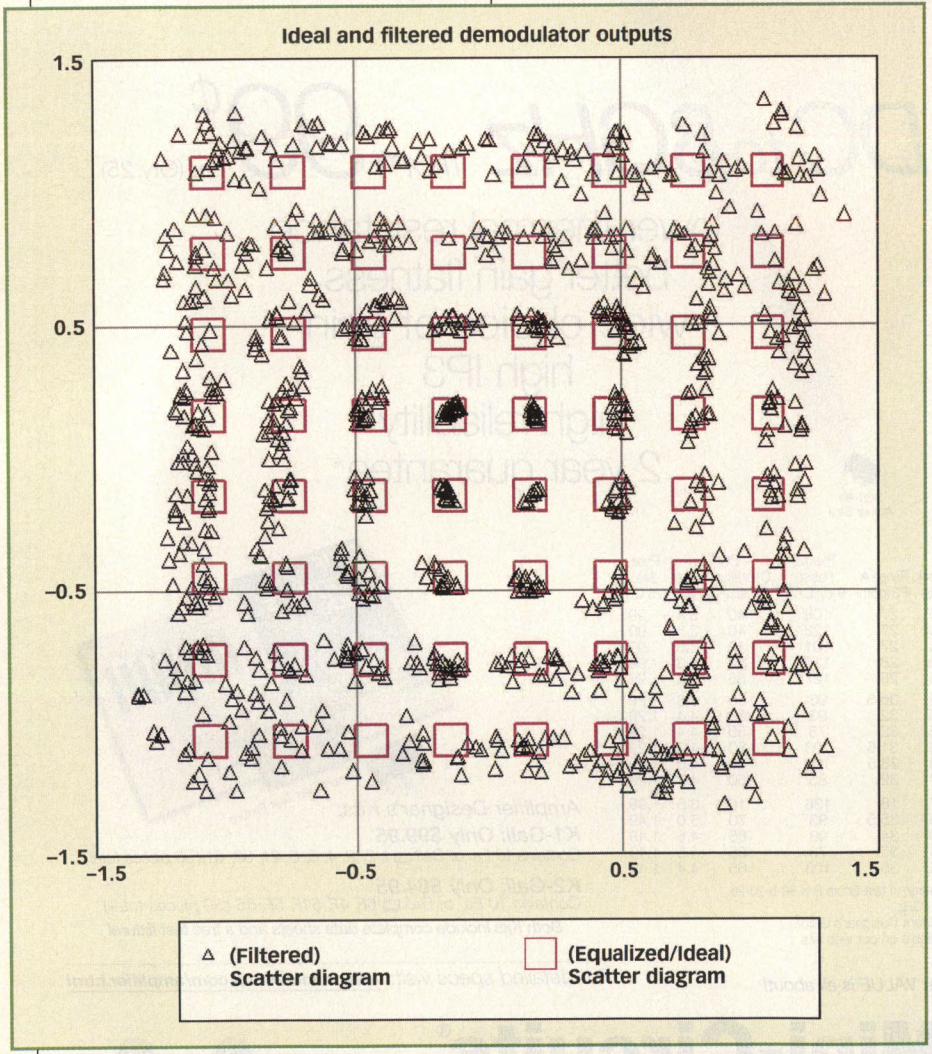
tiplication against the inverse of the complex amplitude/phase estimates. As is the usual case on fading channels, certain frequencies can exhibit low amplitudes, or spectral "nulls." In this situation, information about the reliability of these frequency channels can be passed on to error-control-decoding algorithms. Many coding schemes can accept "soft-decision" information to make better estimates of the original transmitted bits, even in severe fading.

Figure 3 shows the effect of amplitude/phase distortion on the demodulated scatter diagram of an IEEE 802.11a signal operating in 64QAM mode. The signal points shown in squares represent the ideal, or nominal constellation points. These points are actually collected at the output of the equalizer. In this simple experiment, the simulation was run with no noise or fading, so the sounder could obtain perfect estimates of channel amplitude/phase variations. In this experiment, the amplitude/phase variations were created by the introduction of a seven-pole Butterworth filter at the transmitter (Tx) output. The filter amplitude and group-delay response is shown overlaid on the 802.11a spectrum in Fig. 1. The response corresponds to a nonideal Butterworth implementation where some of the resonators have a noninfinite quality factor (Q). This response is generated from a circuit model that runs simultaneously with the communication-link simulation. Although the filter band edges are well-outside the IEEE 802.11a signal spectrum, even the small amount of group-delay distortion within the IEEE 802.11a transmission band causes problems with constellation phase skew. This effect is evident in the unequalized scatter plot, shown as triangles, in Fig. 3. In practice, equalization will not be perfect, since the channel sounder must estimate the channel characteristics in the presence of noise. Even if noise is limited to additive white Gaussian noise (AWGN), the estimated equalization coefficients will have some inaccuracy.



3. These Visual System Simulator 2002 results show amplitude and phase distortion of 802.11a signal in 64QAM mode.

Software simulations can also be used to model performance in the nonideal situation of an AWGN channel. An error rate plot can be created where E_s is the energy transmitted per data channel and N_0 represents the channel-noise power spectral density, normalized to an individual data channel. With such normalization, ideal symbol error probability will be the same as ordinary QAM. In using the software to generate a plot, a bound on ideal symbol-error probability for 64QAM can be overlayed on the simulated results. When such simulations were performed (results not shown here) the error probability for the unequalized system hangs up at a high value, as expected. The error probability for the equalized system is close to ideal, although there is some performance loss due to nonideal equalization.

In summary, the Visual System Simulator 2002 software from Applied Wave Research (El Segundo, CA) can be used to effectively reveal and diagnose potential pitfalls in communication-system designs. This is only possible, however, when software tools provide not only extensive application-specific libraries, but also links to practical hardware models. Only in this case can realistic operational scenarios be accurately assessed. MRF

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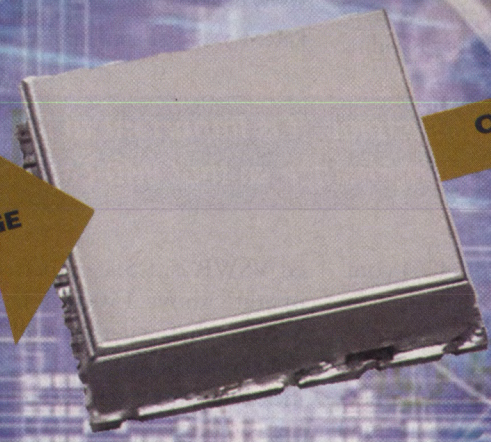

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Roland Hassun of Agilent Technologies (Santa Rosa, CA) introduces the Noise Power Ratio (NPR) concept in his four-page application note entitled, "Noise Power Ratio Measurement Techniques." This concept was manifested 30 years ago for the purpose of providing characterization of the IMD in active circuits in telecommunications systems. NPR can be defined as the ratio of the mean noise power measured in any channel, with all channels loaded with additive white Gaussian noise (AWGN), to the mean noise power measured in the same channel, with all channels but the measured channel loaded with AWGN. The inspection of NPR requires a stimulus that is applicable to the device under test (DUT) and a method of analyzing the DUT output. The stimulus and analysis can each be performed by analog or digital methods. Parameters of the stimulus include average power, occupied signal bandwidth, the bandwidth of the notch, the depth of the notch with respect to the rest of the spectrum (in decibels), the spectral shape of the passband, statistics of the noise, and peak value of the noise signal. This note is available as a free download from the company's website.

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cover story

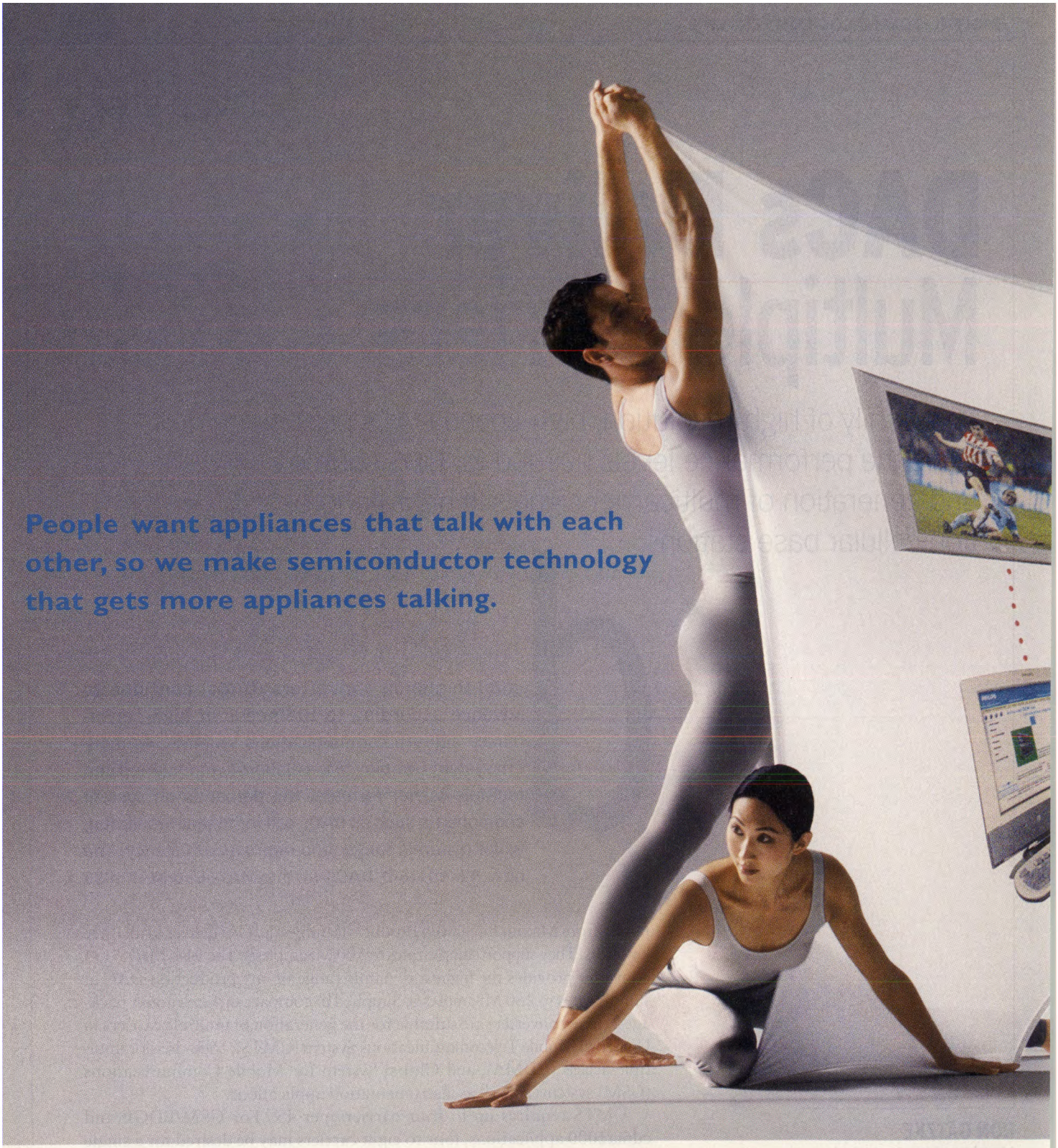
DACs Deliver Multiple Carriers

This family of high-resolution, high-speed DACs provides the performance levels needed for DDS sources and generation of multicarrier signals in next-generation cellular base stations.

RON GATZKE
Member of the Technical Staff
Maxim Integrated Products, Inc., 120 San Gabriel Dr., Sunnyvale, CA 94086; (408) 737-7600, FAX: (408) 737-7194, Internet: www.maxim-ic.com.

Digital-to-analog converters (DACs) continue to advance according to the needs of high-performance modern communications systems. As modern systems employ more elaborate modulation and multiple-carrier formats, the demands on system components such as DACs call for higher resolution, wider dynamic range, and improved efficiency. The new 12- to 16-b DACs in the MAX5886-MAX5888 family from Maxim Integrated Products (Sunnyvale, CA) deliver in all three key areas. They support sample rates to 500 MSamples/s. The 14-b MAX5195 converter provides the highest dynamic range of any production DAC at sample rates to 260 MSamples/s. Supplied in compact surface-mount packages, these converters are suitable for the generation of multiple carriers in Universal Mobile Telecommunications System (UMTS), code-division-multiple-access (CDMA), and Global System for Mobile Communications (GSM) systems as well as instrumentation applications.

UMTS requires up to four carriers per Tx. For GSM/EDGE and cdma2000 applications, four to eight carriers may be desired for a single transmitter. The generation of multiple carriers requires substantially more dynamic range in the signal path. Fortunately, high-speed DACs in the MAX5888 family can support up to four UMTS carriers, including appropriate margins with respect to the UMTS standard. As a further refinement, these DACs allow correction of power-amplifier (PA) nonlinearities by introducing digital predistortion to the signals to be amplified. That requirement alone can increase the required signal bandwidth by a factor of three to five. Thus, the signal bandwidth necessary for four UMTS carriers (up to 100 MHz) calls for higher sample rates and higher analog



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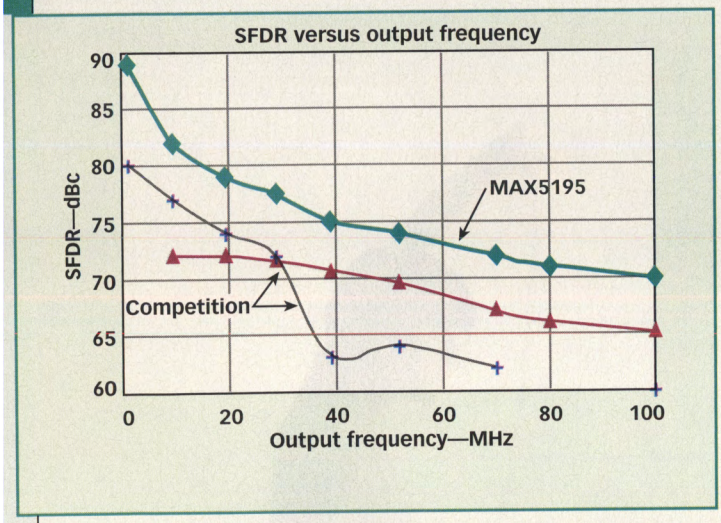
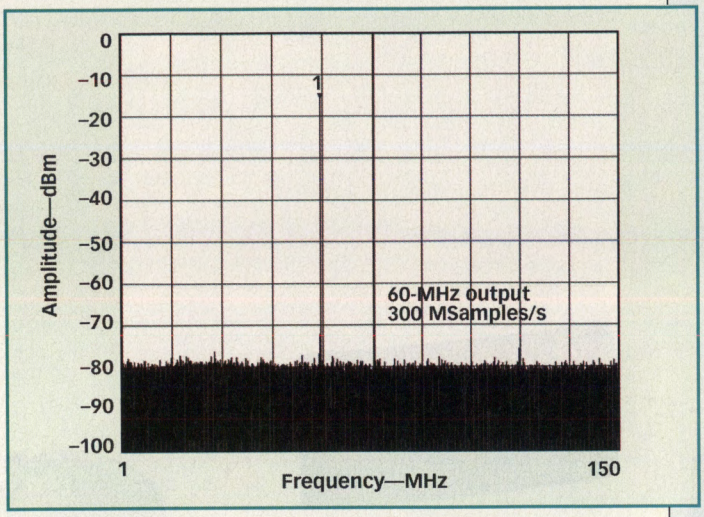


1. This SFDR graph compares the MAX5195 to the best-available competitive devices for a range of output frequencies.



2. The typical SFDR of the MAX5888 for a 60-MHz output frequency is shown over a 100-MHz bandwidth.

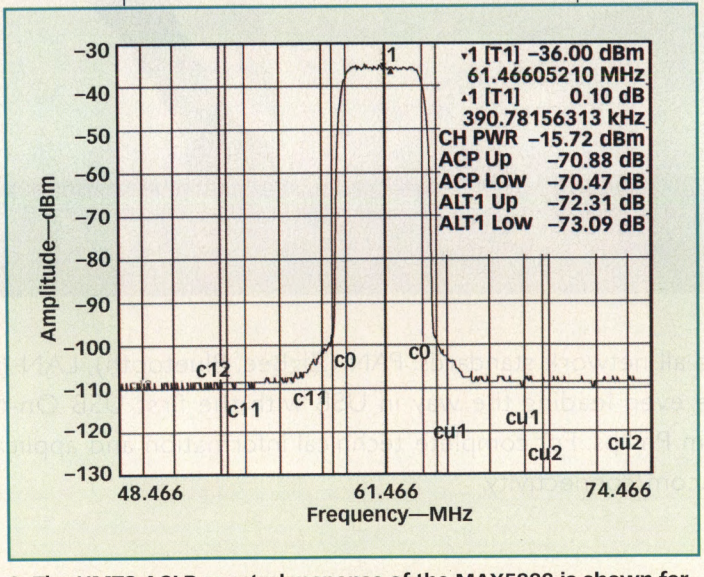
output frequencies. The MAX5888's 500-MSamples/s update rate is designed for these applications.

Transmit waveforms in GSM/EDGE systems demand even more dynamic performance from the DAC. The generation of multicarrier signals pushes spurious-free-dynamic-range (SFDR), intermodulation-distortion (IMD), and signal-to-noise-ratio (SNR) values to extremes. The company's highest-performance DAC for multicarrier applications is the 14-b, 260 MSamples/s MAX5195. It provides outstanding SFDR, SNR, and IMD performance for these systems, with –77-dBc SFDR for a 19.4-MHz output signal when operating from a single +5-VDC supply. The new MAX5888 nearly matches the dynamic performance of the MAX5195 for multicarrier systems, as well as for direct-digital-synthesis (DDS) applications, while dissipating only 235 mW from a single +3.3-VDC supply.

For a 50-MHz output frequency and 400-MSamples/s sample rate, the MAX5888's SFDR exceeds 67 dB. It also provides an SNR level of –155 dBc/Hz and a two-tone IMD of –72 dBc for output frequencies of 80 MHz. The sampling rate for these performance levels is 500 MSamples/s. Digital data to the new DACs is applied through an low-voltage-differential-signalling (LVDS) interface. An LVDS-based logic family supports 500-MSamples/s data rates effectively, and the digital signals' differential input swings help reduce system-level noise at the digital interface.

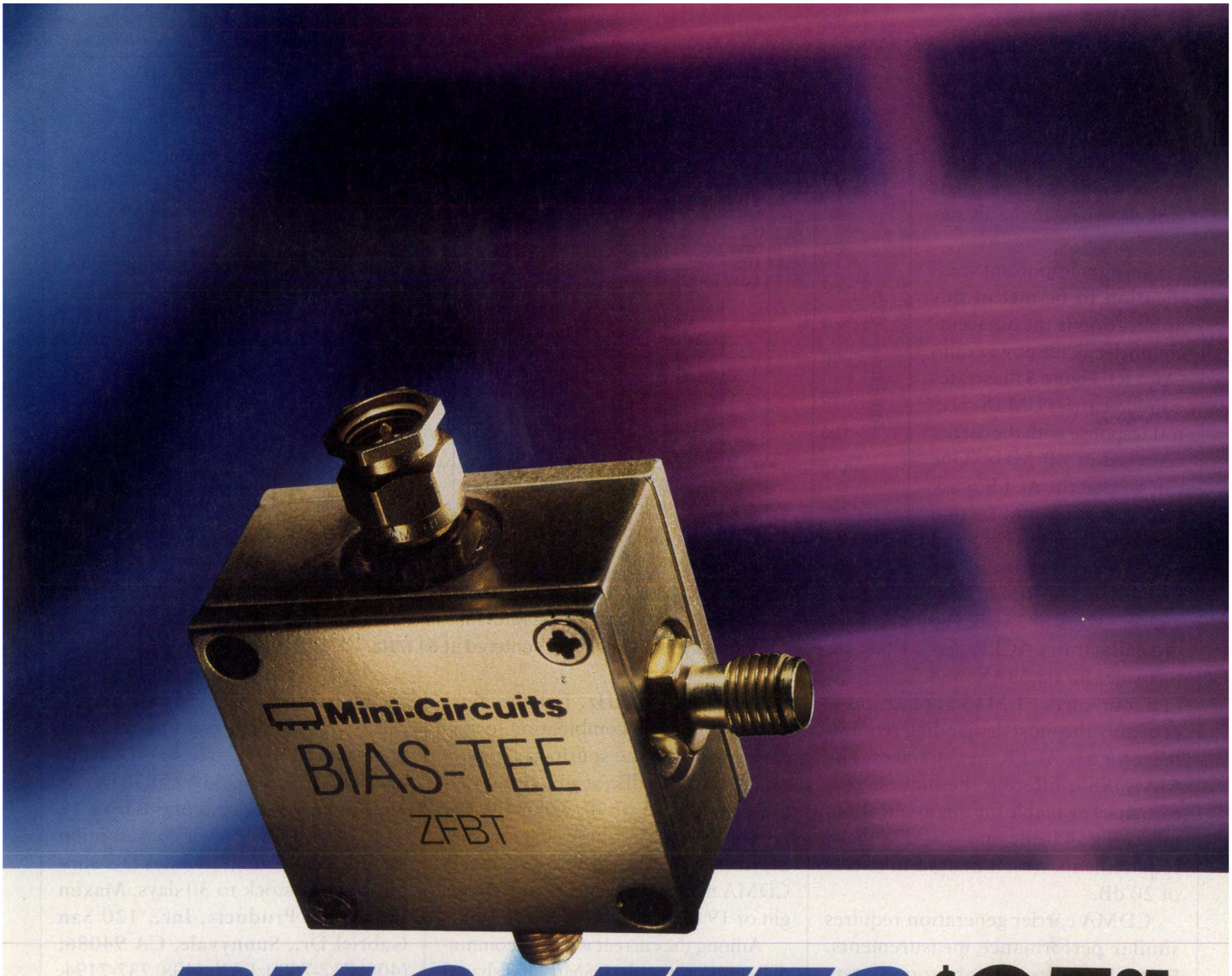
The SFDR performance of the new MAX5886-MAX5888 family is exceeded only by that of the MAX5195 **(Fig. 1)**. This DAC also delivers industry-leading SNR performance of –160 dB/Hz. Its two-tone IMD performance of –87 dBc for an output frequency of 32 MHz is also outstanding. The digital interface of the 14-b MAX5195 DAC incorporates differential low-voltage positive-emitter-coupled logic (LVPECL), which—similar to LVDS—reduces the system-level noise associated with high-speed digital data transmission.

The MAX5886-MAX5888 family and the MAX5195 DACs are available in miniature QFN packages: the MAX5886-MAX5888 units are supplied in 68-pin housings, while the MAX5195 is supplied in a 48-pin package. The leadless QFN packages combine small physical size (as small as 7 × 7 mm) with excellent thermal and electrical characteristics.



3. The UMTS ACLR spectral response of the MAX5888 is shown for single fully loaded carrier at an output frequency of 61 MHz.

Consider a multicarrier UMTS application that includes digital predistortion techniques. These applications combine demanding dynamic performance with 100-MHz signal bandwidths. The UMTS mask for spurious emissions requires that spurious products within a 1-MHz measurement bandwidth be no greater than –58 dBc. **(Figure 2** shows the spectral output for a single tone at 60 MHz and a sample rate of 300 MSamples/s). Clearly, the MAX5888's margin over a desired 100-MHz bandwidth (more than 8 dB



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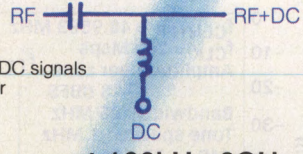

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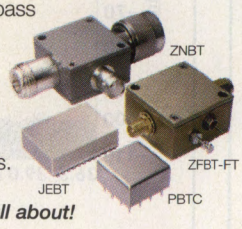

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▲ZFBT-6GW	0.1-6000	0.15	0.6	1.0	25	40	30	1.13:1	89.95
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★ZNBT-60-1W	2.5-6000	0.2	0.6	1.6	75	45	35	1.35:1	82.95
■PBTC-1G	10-1000	0.15	0.3	0.3	27	33	30	1.10:1	25.95
■PBTC-3G	10-3000	0.15	0.3	1.0	27	30	35	1.60:1	35.95
■PBTC-1GW	0.1-1000	0.15	0.3	0.3	25	33	30	1.10:1	35.95
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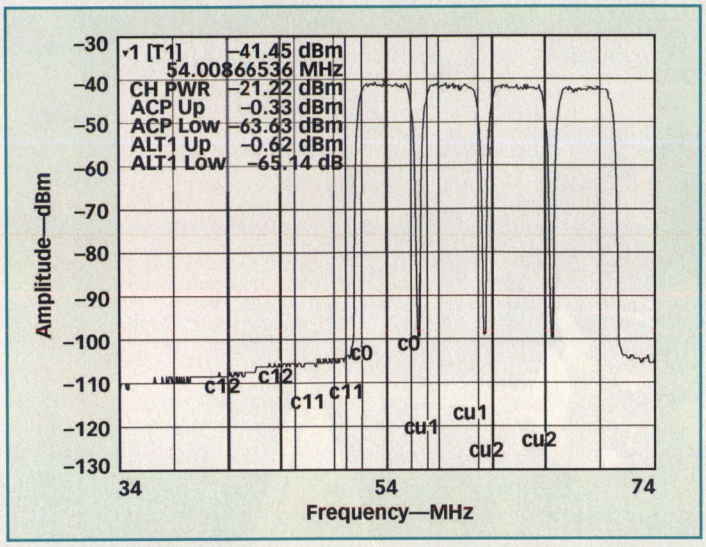
greater than the mask requirements) supports relaxed margins elsewhere in the Tx signal chain.

Another important specification to be met in this application is the adjacent-channel leakage power ratio (ACLR). **Figure 3** illustrates a single-carrier UMTS spectral response with the carrier centered at 60 MHz. One can see that the ACLR mask levels for first and second adjacent channels (–45 and –50 dBc, respectively) are met with comfortable margins in excess of 25 dB. **Figure 4** illustrates ACLR performance for the MAX5888 in a four-carrier UMTS application—probably the most demanding requirement for any ACLR measurement. The MAX5888, offering the highest performance available for this application, meets the -45-dBc and –50-dBc mask requirements with a margin in excess of 20 dB.



4. The UMTS ACLR spectral response of the MAX5888 is shown for a test case, with four fully loaded carriers centered at 61 MHz.

CDMA carrier generation requires similar performance measurements. **Figure 5** depicts an eight-tone system where the tones are separated by 1 MHz, at an intermediate frequency (IF) centered at 30 MHz. For the most demanding mask combination for the various bands, the spurious-emission mask level is –59 dBc, at an assumed output-power level of 40 W for the Tx. For this worst-case sinusoidal test-simulation case, the MAX5888 meets CDMA mask requirements with a margin of 19 dB.

Among the current wireless-communications protocols, GSM/EDGE-based architectures impose the greatest dynamic-range requirements. Limitations in DAC performance have made multicarrier Txs impractical in the past, but the MAX5195 lifts that restriction—as shown by its IMD performance for four sinusoid tones with 1-MHz spacing between the tones **(Fig. 6)**.

The IMD mask limit of –70 dBc is easily met with an 8-dB margin by the MAX5195. By using a smaller backoff in the output power level (only –15 dB from full scale), the performance can be improved by 6 dB. The MAX5195's SNR of –160 dBc/Hz makes the device ideal for multicarrier applications.

While the MAX5195 offers unrivaled dynamic-range performance when operating from a single +5-VDC supply, the MAX5886-MAX5888 family of devices provide resolutions from 12 to 14 b with low power consumption from lower-voltage, +3.3-VDC supplies. P&A: stock to 30 days. **Maxim Integrated Products, Inc., 120 San Gabriel Dr., Sunnyvale, CA 94086; (408) 737-7600, FAX: (408) 737-7194, Internet: www.maxim-ic.com.**

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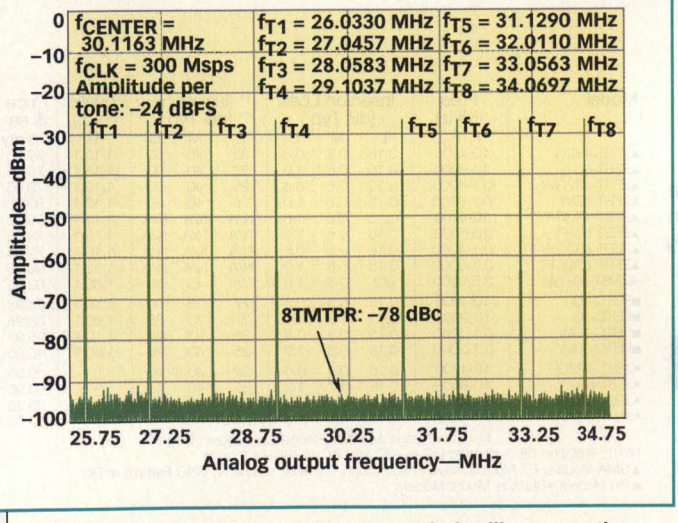
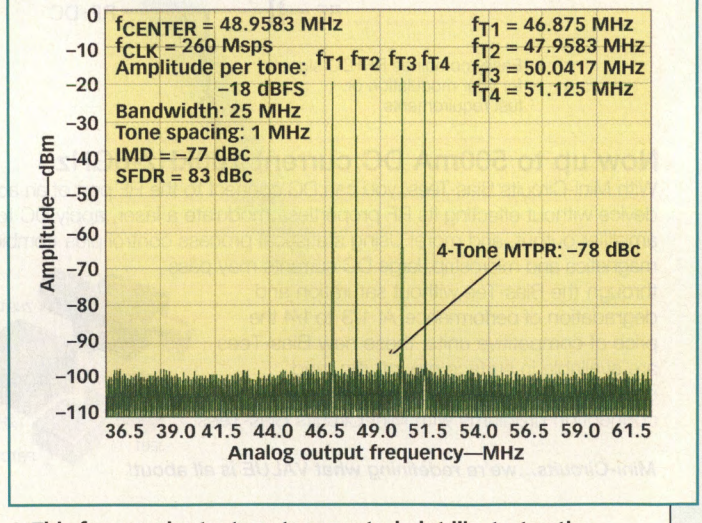


5. This eight-carrier test-vector spectral plot illustrates the MAX5888's superior multi-tone IMD performance for CDMA applications. The selected output frequency is centered at 30 MHz.



6. This four-carrier test-vector spectral plot illustrates the MAX5195's superior multi-tone IMD performance for GSM applications. The output frequency is centered at 48 MHz.

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Oscilloscope Conquers Speed And High Bandwidth

In addition to the high signal fidelity derived from its all-SiGe front end, this digital storage scope flaunts fast display updates and user customization.

NANCY KONISH
Technology Editor

Relief has come to engineers working with very fast edges or long, complex high-speed signals. The WaveMaster model 8600A digital storage oscilloscope from LeCroy Corp. (Chestnut Ridge, NY) can capture signals with up to a 6-GHz bandwidth and a 75-ps rise time. At the same time, it promises superb signal fidelity. The scope can perform many standard measurements up to 100 times faster than other oscilloscopes. It also provides users with the ability to create customized parameter measurements or waveform-math functions and insert them into the scope's user interface **(see figure)**.

The instrument inherits its speed from LeCroy's X-Stream technology. This is an extremely fast streaming architecture for handling and analyzing data in a digital oscilloscope. The front end of the X-Stream architecture starts with silicon-germanium (SiGe) amplifiers and analog-to-digital converters (ADCs) that track the incoming signal. The signal is digitized at 10 GSamples/s on each of the four input channels. Data is then streamed to fast complementary-metal-oxide-semiconductor (CMOS) memory chips that can accept the 10-GB/s data rate for up to 48 million points of acquisition.



Thanks to its X-Stream architecture, the WaveMaster series was designed for the measurement and analysis of waveforms—not only the viewing of signals.

Though the X-Stream architecture begins with hardware, much of its power and speed actually comes from its software algorithms. They enable the data packets and the enabling routines that perform measurements on those packets to simultaneously reside in the microprocessor cache. This eliminates the trade-offs between long record lengths and fast processing. Due to its SiGe trigger circuit, the WaveMaster 8600A also offers extremely low trigger jitter and maximum trigger sensitivity at high bandwidths. At 1 PPM, the scope's high-stability internal sample clock ensures precise timing measurements. Up to 1 Mpoint can be captured with the standard memory in four-channel mode.

The display has a high resolution of 800 × 600 pixels. It features a 20-percent larger viewing area for the clear display of signals. When coupled with the easy-to-use graphical-user interface (GUI), the front-panel controls allow the user to control the scope from the touchscreen, front panel, mouse, or a combination of these elements. **LeCroy Corp., 700 Chestnut Ridge Rd., Chestnut Ridge, NY 10977-6499; (845) 425-2000, Internet: www.lecroy.com.**

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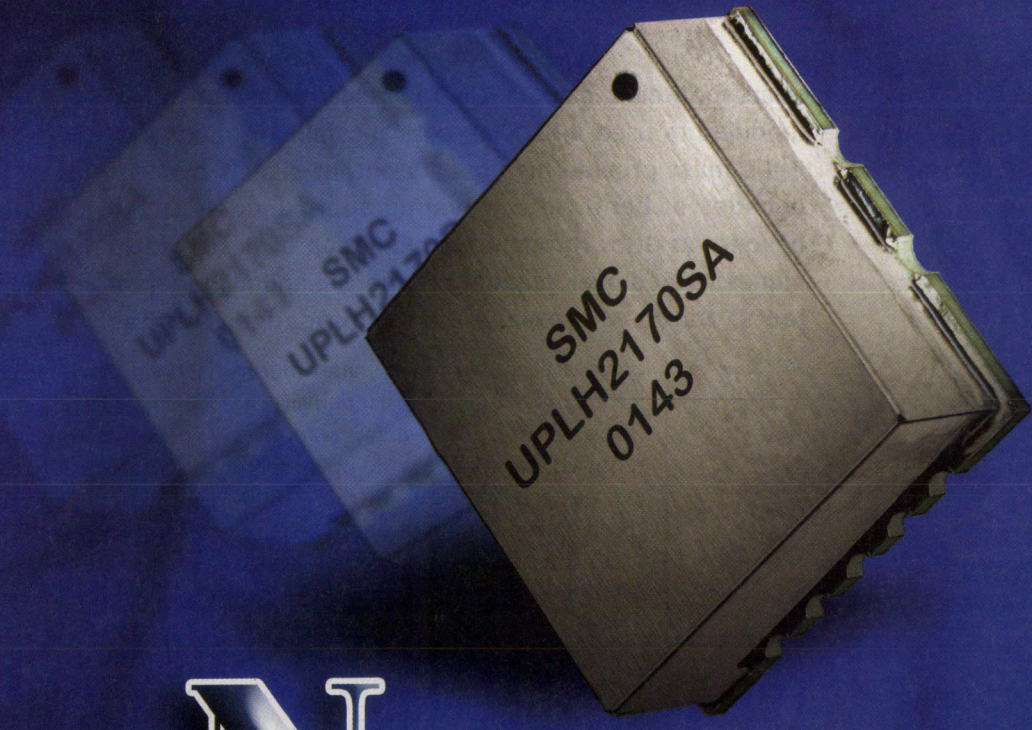

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Broadband Amplifiers Drive OC-768 Modulators

These broadband amplifiers deliver the voltages needed to drive $LiNO_3$ modulators at rates to 43 Gb/s with input signals as low as +0.25 VDC peak to peak.

Drivers for lithium niobate ($LiNO_3$) or electro-absorptive (EA) modulators used in OC-768 optical-communications systems must provide high-quality output signals over six decades of bandwidth, covering approximately DC to beyond 40 GHz. Through a combination of design techniques refined over years of commercial and military projects, Narda Microwave-East (Hauppauge, NY) has created a family of broadband-modulator driver amplifiers that delivers the flat gain and group-delay responses required to produce wide-open open-eye patterns required in these high-speed optical-communications systems.

In addition to the model FO-MDA-40-00 modulator driver amplifier **(see figure)**, the company also offers 20- and 40-GHz clock-driver amplifiers, 10-, 20-, and 40-GHz clock oscillators, broadband-data amplifiers, and OC-768 clock-recovery circuits.

The FO-MDA-40-00 modulator driver amplifier can be specified with +6.0- or +7.5-VDC outputs from $LiNO_3$ modulators, or with a +4-VDC output from EA modulators. The +7.5-VDC version delivers its rated output level with input signals as low as +0.25 VDC peak to peak. All of the models provide a +3-VDC output-amplitude control range and incorporate eye-crossing symmetry adjustment. A dither voltage can be superimposed onto the output waveform by applying a sinusoidal input to the amplitude-adjustment control pin. An optional output-voltage-level detector can be provided that allows the amplifier's output voltage to be continuously monitored for external amplitude adjustment. The detector is temperature compensated to ensure accuracy over the operating range of 0 to +80°C. The minimum operating frequency of standard units is 80 kHz, although a version with 30-kHz, low-frequency 3-dB roll-off is also available. For all units, the input and output return loss is 10 dB, rise and fall times are 5 ps, and root-mean-square (RMS) jitter is 0.5 ps.

The FO-MDA-40-00 is available as complete unit that includes all the control circuits, as an RF hybrid alone with design information for an external control board, or as a special unit with customer-defined control functionality. The family of amplifiers operates from +9 VDC at 300 mA and –9 VDC at 20 mA, is internally regulated, and has automatic DC bias sequencing. **Narda Microwave-East, 435 Moreland Rd., Hauppauge, NY 11787; (631) 231-1700, FAX: (631) 1711, e-mail: nardaeast@L-3com.com, Internet: www.nardamicrowave.com.**

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JACK BROWNE
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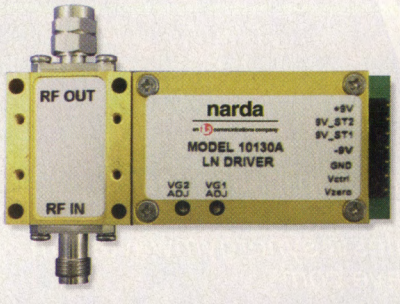
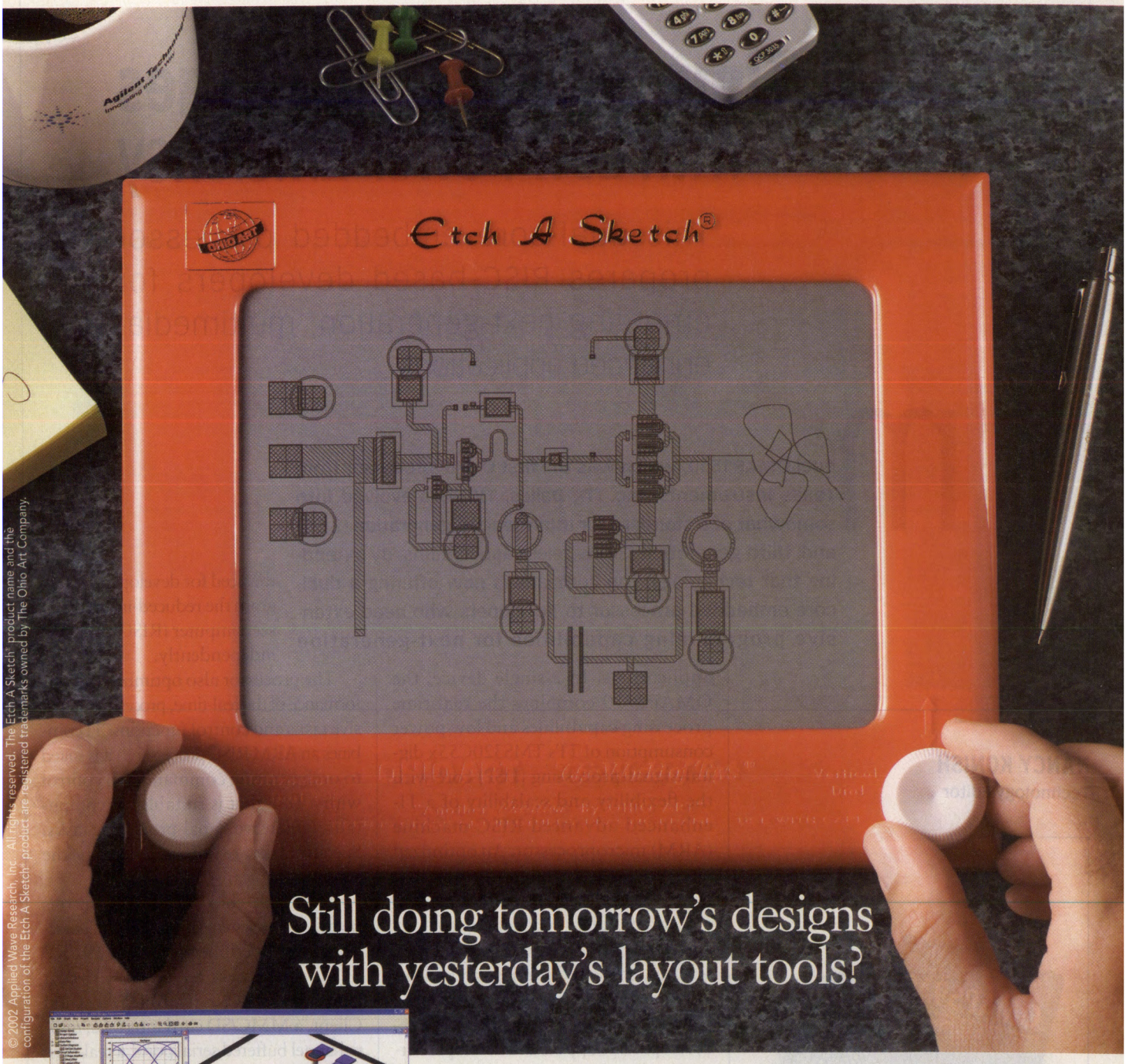


The FO-MDA-40-00 family of modulator driver amplifiers deliver healthy output voltages when working at frequencies as high as 43 GHz.

AWR



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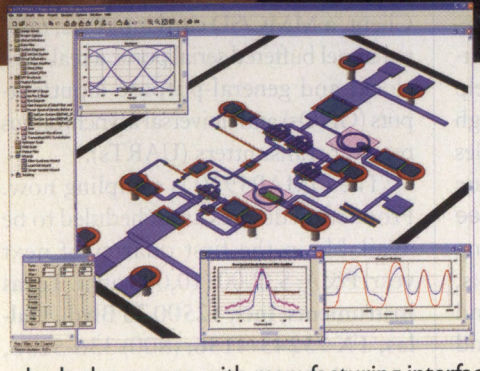

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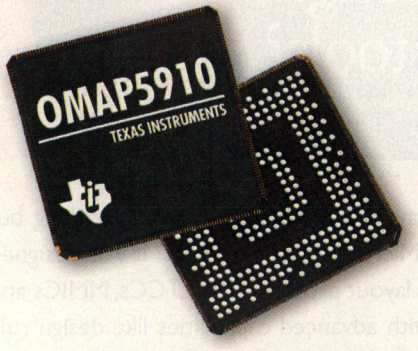
Real-Time Processing Merges With Low Power Efficiency

This dual-core embedded processor prepares RISC-based developers for emerging next-generation, multimedia-enhanced applications.

Model OMAP1510, which was the first OMAP processor from Texas Instruments, Inc. (TI; Dallas, TX), has evolved into somewhat of a standard for intermediate-generation (2.5G) and third-generation (3G) wireless applications. By extending that technology, the company is now offering a dual-core embedded processor to developers who need extensive programming capabilities for next-generation applications. In a single device, the OMAP5910 combines the real-time processing capabilities and low power consumption of TI's TMS320C55x digital-signal-processing (DSP) core with the flexibility and scalability of a TI-enhanced advanced RISC machine (ARM) microprocessor. An optimized interprocessor communication mechanism makes it easy to use.

NANCY KONISH
Technology Editor



By supporting leading operating systems and software platforms, the OMAP5910 enables developers to provide new applications while conserving time and power.

For emerging applications such as digital media, biometrics, location-based services, enhanced gaming, and telematics, developers need programming options. By combining with TI's software-development support and developer network, the OMAP5910 promises to help designers create applications with high performance in less time. It also enables embedded developers to program using familiar development environments **(see figure)**. The processor supports leading operating systems, such as VxWorks, Nucleus PLUS, Windows CE.net, and Linux. To save programming time and complexity, the built-in interprocessor communication mechanism eliminates the need for developers to program the reduced-instruction-set computer (RISC) and DSP independently.

The processor also optimizes the performance of the real-time, processing-intensive tasks and control functions. TI combines an ARM RISC processor that is suited to orchestrating command and control with a DSP that is suitable for computation-intensive signal-processing tasks. Specific tasks are thus completed by the most appropriate device.

The single-chip OMAP5910 also is notable for its system-on-a-chip (SoC) functionality. Its peripherals include 192 KB of random-access memory (RAM), a Universal Serial Bus (USB) 1.1 Host and Client, a MMC/SD card interface, multichannel buffered serial ports, a real-time clock, and general-purpose input/outputs (GPIOs) and universal asynchronous receiver transmitters (UARTs).

The OMAP5910 is sampling now. Production devices are scheduled to be available in the first quarter of next year. P&A: $32.00 (10,000 qty.). **Texas Instruments, Inc., 12500 TI Blvd., Dallas, TX 75243-4136; (800) 336-5236, www.ti.com.**

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RF ICs Complement Full Device Portfolio

Low-cost RF ICs are now available from a long-time device supplier that is probably better known for its power-management circuits, operational amplifiers, and data converters.

JACK BROWNE
Publisher/Editor

Integrated-circuit (IC) suppliers are often known for a handful of circuit functions, such as microcontrollers or data converters. But Linear Technology Corp. (Milpitas, CA), already well-established for their power ICs, operational amplifiers, and digital-to-analog converters (DACs), is in the process of establishing themselves as a major supplier of RF ICs with the introduction of several new devices, including a high-linearity 3-GHz downconverting mixer, a 1-GHz RF power detector, and modulator/demodulator.

For example, the LT5512 is a high-linearity active downconversion mixer specified for input frequencies from DC to 3 GHz. The mixer offers input third-order intercept point (IP3) of +20 dBm at 950 MHz and +17 dBm at 1900 MHz. The IC includes a differential local-oscillator (LO) buffer amplifier (allowing it to work with single-ended and differential LO signals) and active double-balanced mixer. It provides typical conversion gain of 1 dB at 1900 MHz. The single-sideband (SSB) noise figure is 14 dB at 1900 MHz. The mixer, which is designed for supplies of +4.50 to +5.25 VDC, is supplied in a QFN package measuring just 4 × 4 mm.

The LTC5507 is an RF power-detector IC with input-frequency range of 100 kHz to 1 GHz and power-detection range of –34 to +14 dBm. The LTC5507 offers a modulation bandwidth of 1.5 MHz to handle such applications as envelope detectors, wireless data modems, amplitude-modulation (AM) and amplitude-shift-keying (ASK) demodulators, mobile telephones, and optical power detectors. The IC features an on-chip temperature-compensated Schottky-diode peak detector with extended dynamic range and output buffer to maintain power-detection accuracy over a temperature range of –40 to +85°C. It is designed to operate on supplies from +2.7 to +6.0 VDC with supply current of only 550 µA and low shutdown current of less than 2 µA.

The LT5503 in-phase/quadrature (I/Q) modulator/mixer also operates on supplies of +1.80 to +5.25 VDC. It is designed for input carrier frequencies from 1.2 to 2.7 GHz (at power levels from –20 to –10 dBm). It supports a 120-MHz I/Q input modulation bandwidth, and delivers modulated output signals of –3.0 dBm at 2.5 GHz. An on-board variable-gain amplifier provides output-power reduction in three steps (4.5, 9.0, and 13.5 dB) with 100-ns switching speed. **Linear Technology Corp., 720 Sycamore Dr., Milpitas, CA 95035; (408) 432-1900, FAX: (408) 434-0507, Internet: www.linear.com.**

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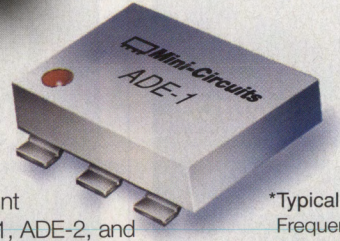

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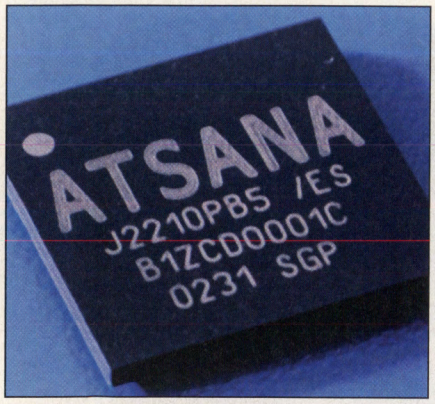

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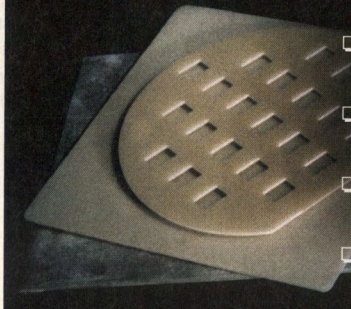

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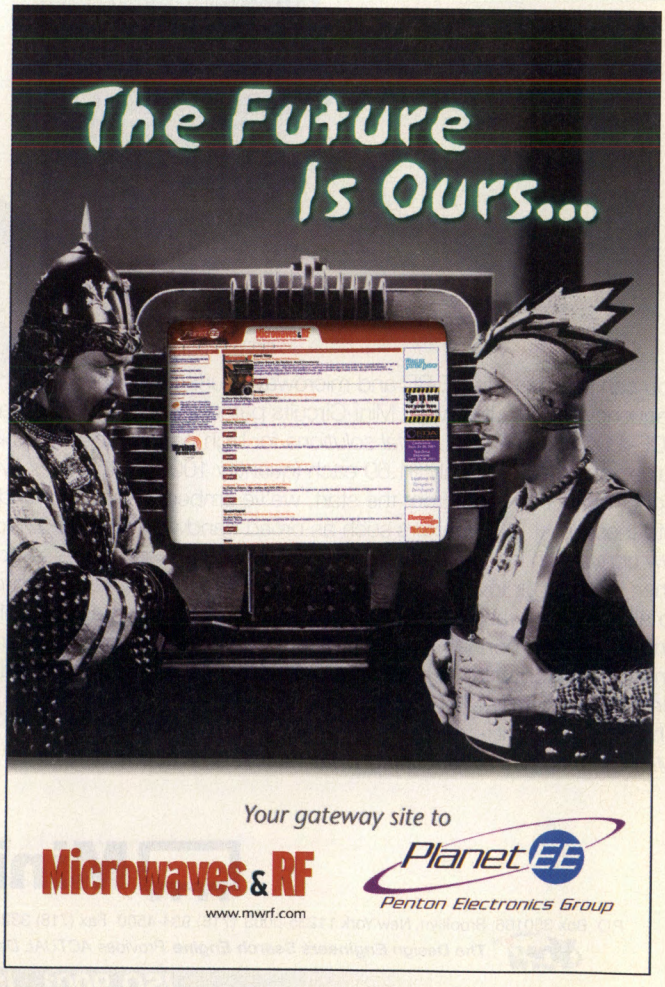

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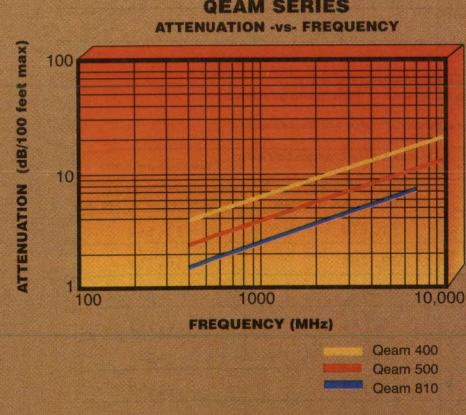

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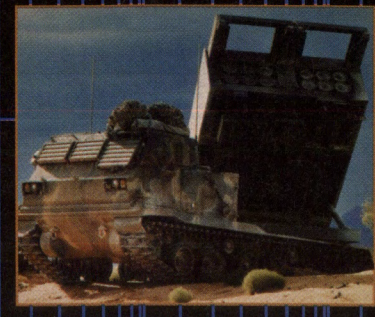





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16. Publication of Statement of Ownership
☒ Publication required. Will be printed in the Nov. 2002 issue of this publication. ☐ Publication not required.

17. Signature and Title of Editor, Publisher, Business Manager, or Owner: Preston L. Vice, Senior Vice President — Date: 10/1/02

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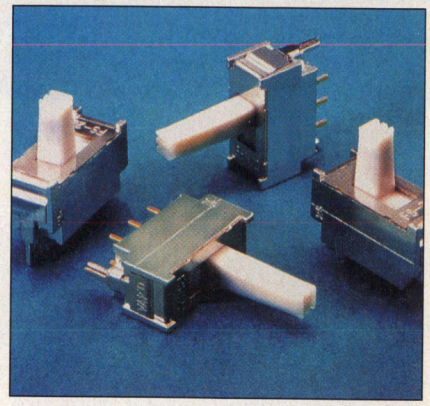

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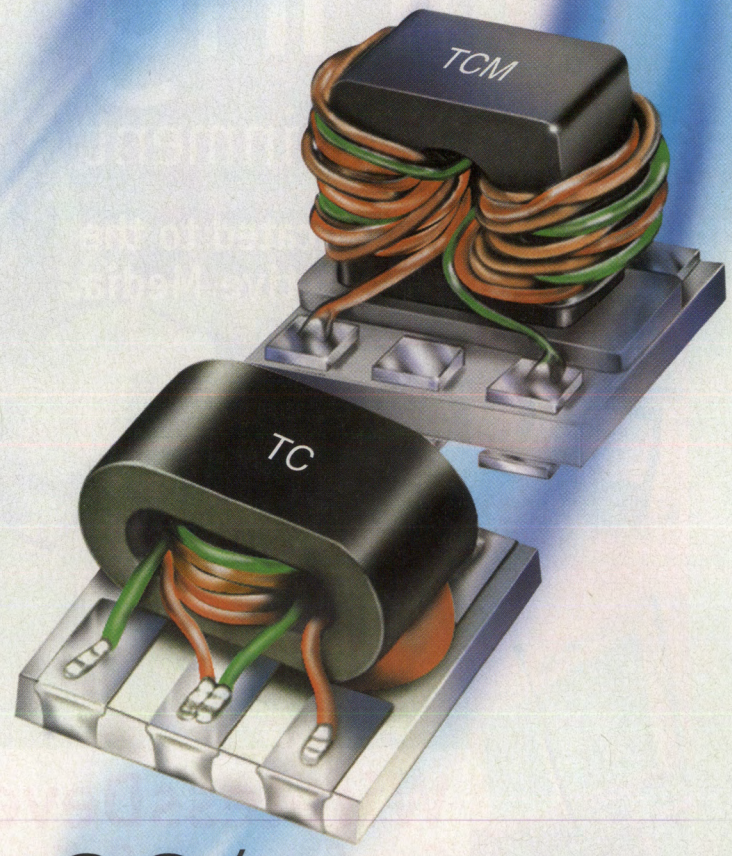

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TC4-11	50/12.5D	2-1100	5-700	1.59
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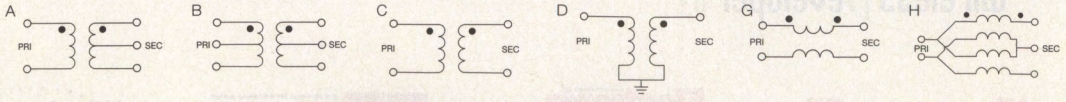

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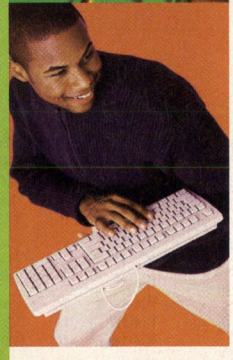

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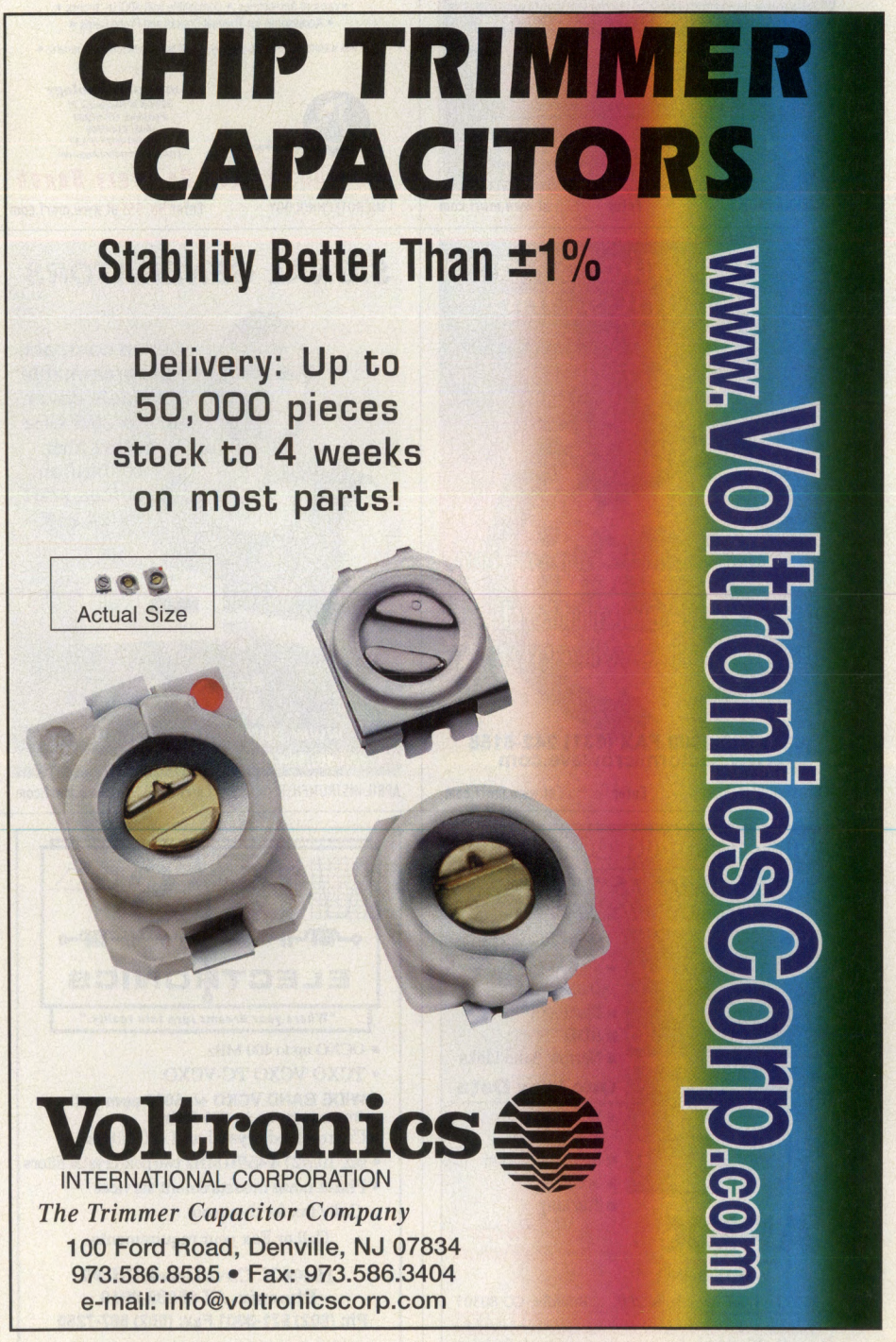

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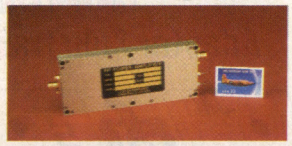

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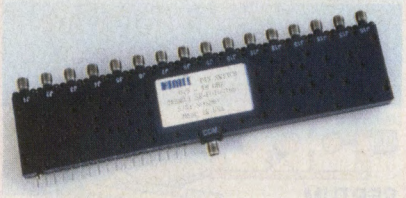

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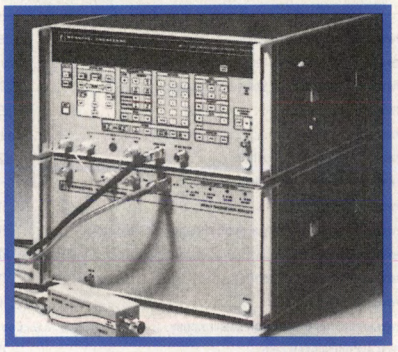

THE COVER OF May 1982 featured the new 10-MHz-to-18-GHz model VM-24 signal-generator calibrator from Weinschel Engineering (Gaithersburg, MD). The company celebrates their 50 years in the microwave industry this month (see p. 33).

next month

Microwaves & RF December Editorial Preview
Issue Theme: Communications

News

December will feature a host of special items, including a sneak preview of the industry's longest-running wireless design conference, Wireless Systems Design Conference & Expo (www.wsdexpo.com). This preview will include summaries of the key technical presentations to be made next February in San Jose, CA. In addition, December will also offer a special report on emerging MEMs technology and how it is being applied in the fabrication of switches, relays, and other miniature components. Finally, the December news section will take an inside look at one of the high-frequency industry's leading suppliers of wafer-probe systems and high-performance mask-alignment equipment, nestled deep in the hills of Vermont's Green Mountains.

Design Features

The December issue will cover Communications from a variety of angles. A longtime contributor will offer a review of oscillator-design fundamentals, while designers of buffer amplifiers will explain how specific models can be used to improve VCO phase noise. An integrated approach to LNAs involves the use of miniature power combiners, while creators of tiny embedded antennas will explore their methods for improving isolation. Finally, a Canadian expert in EM-field theory will explore different antenna designs for millimeter-wave wireless indoor applications.

Product Technology

A new family of low-power, high-speed DDS ICs will headline the December Product Technology section. Featuring up to 14-b resolution and sampling rates to 400 MSamples/s, these agile sources are designed to operate on less than 250 mW of power. Additional product features examine a chip-sized antenna design capable of supporting multiple wireless communications bands, a path-fade simulation system for evaluating the performance of wireless systems, and a line of low-loss substrates for high-frequency circuits. In addition, December will unveil the dozen or so products selected by the editors of *Microwaves & RF* as the Top Products of 2002.

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DC- 4.0	5	N4405 *	4405-*
DC- 4.0	10	N4410 *	4410-*
DC- 4.0	25	N4425 *	4425-*
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5.85- 8.20	500	137-925	1000	137-920
7.05-10.0	425	112-925	600	112-920
7.00-11.0	325	102-925	500	102-920
8.20-12.4	225	90-925	500	90-920
12.4 -18.0	200	62-925	250	62-920

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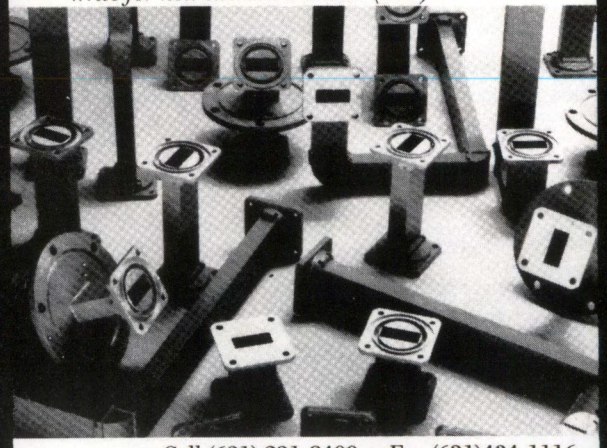

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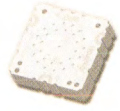

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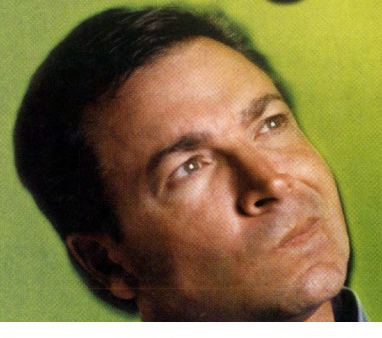

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