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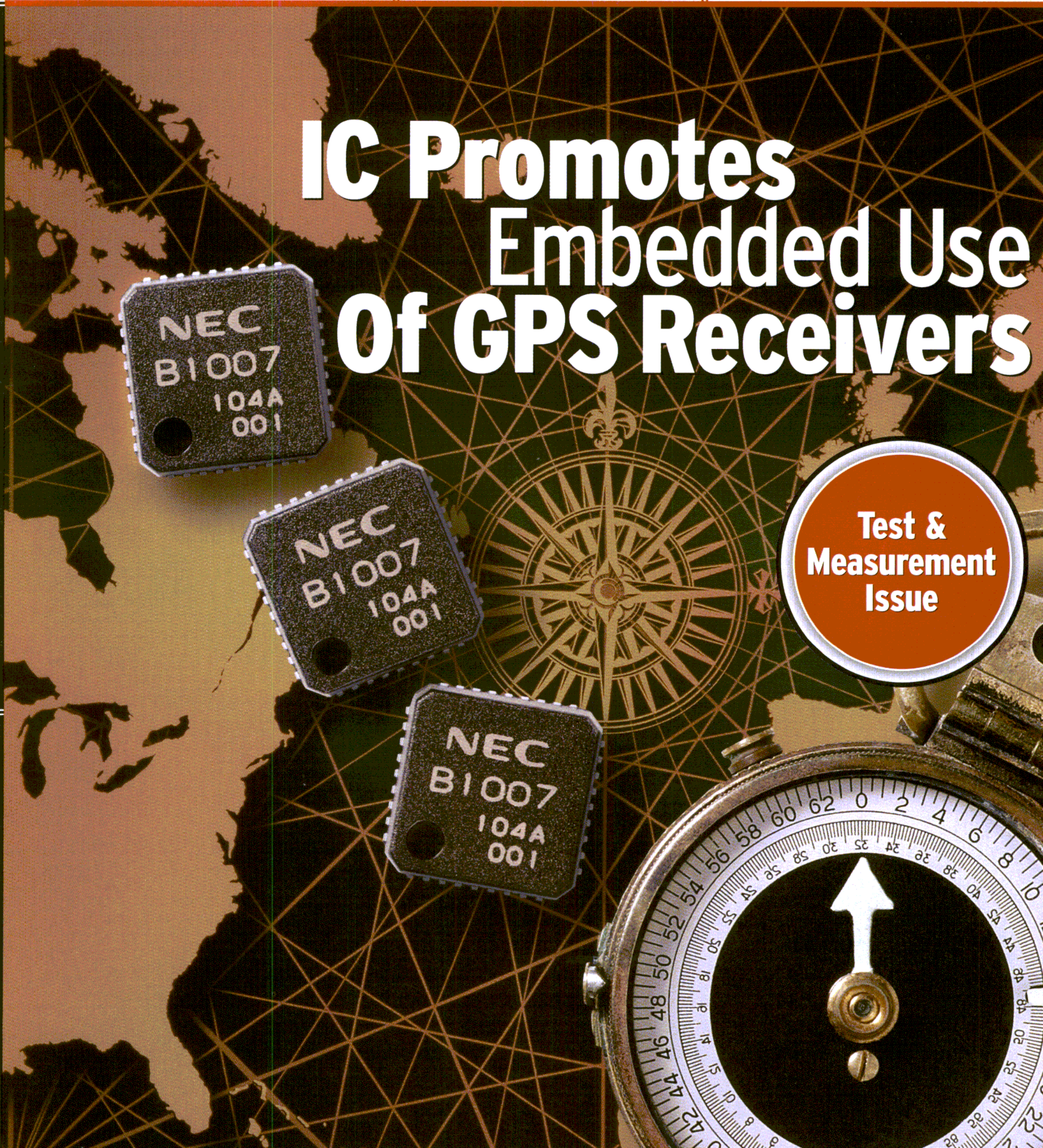
News
Tracking trends in test equipment

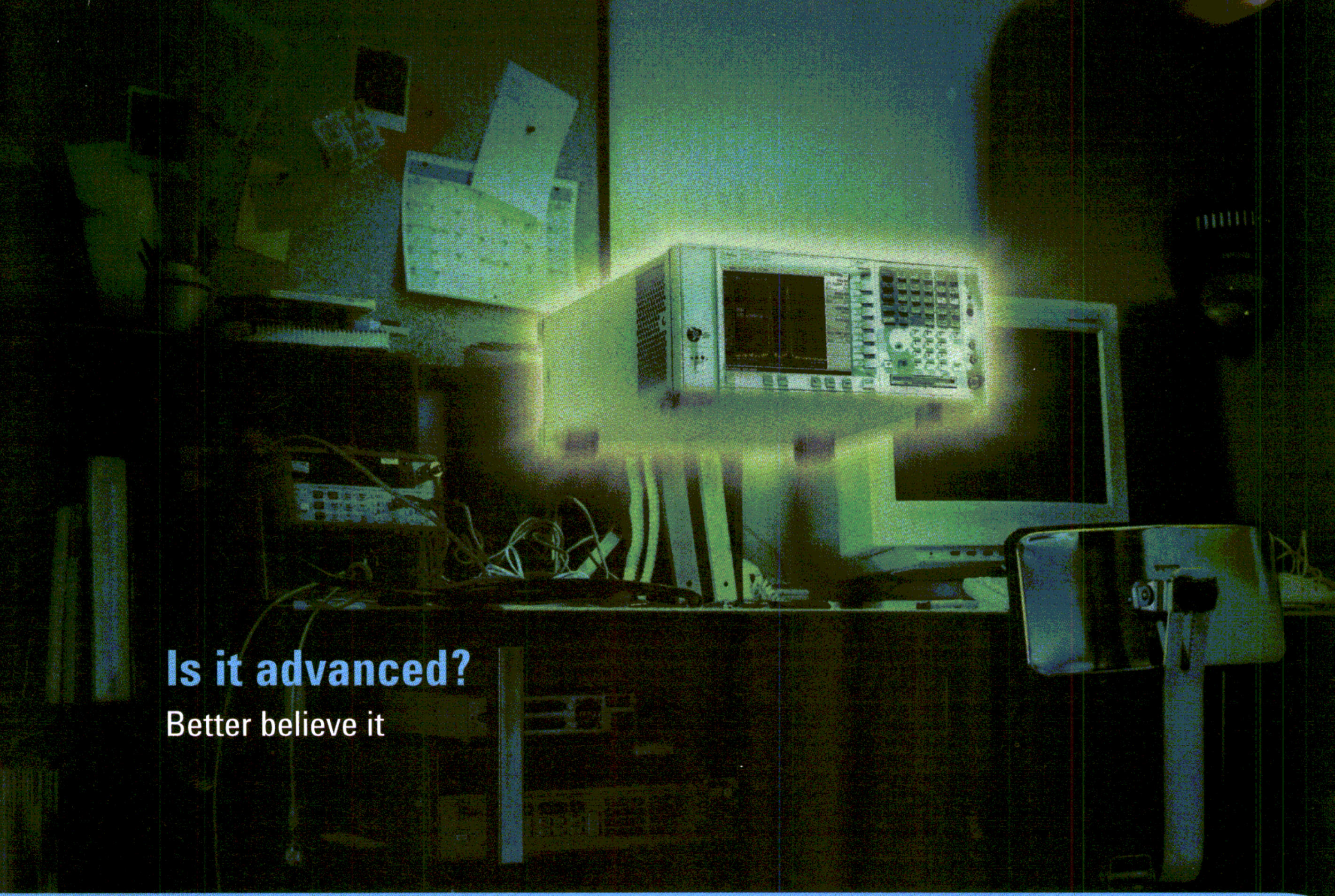
Design Feature
Assemble broadband channel emulators

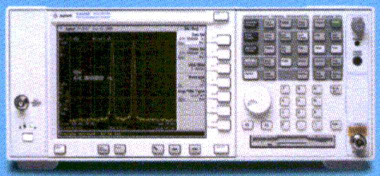
Product Technology
Modulators drive 10-Gb/s optical systems



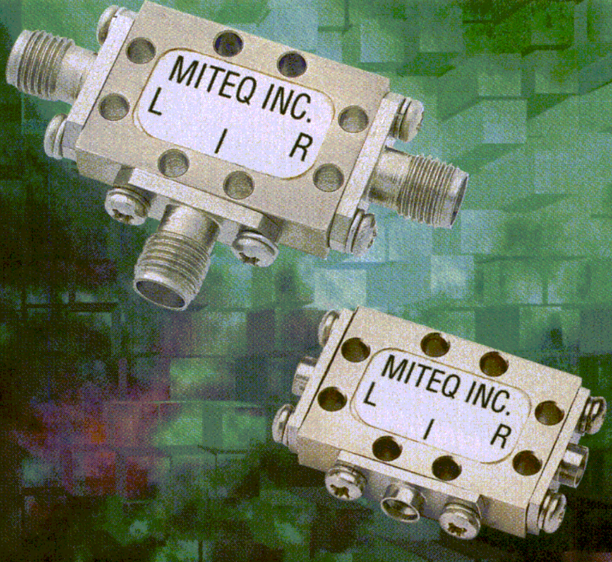
IC Promotes Embedded Use Of GPS Receivers

Test & Measurement Issue


Is it advanced?
Better believe it



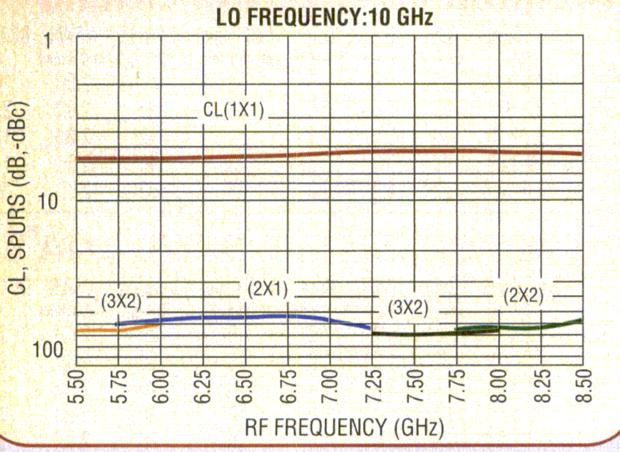
LOW SPURIOUS
SPACEBORNE MIXERS



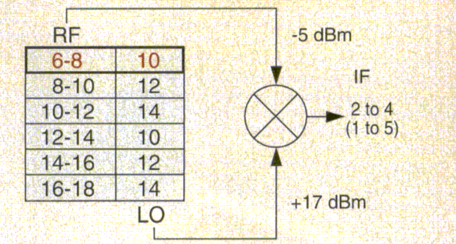
FEATURES:

- Broadband operation
- Minimal variation in conversion loss
- High IP3 and 1 dB compression versus LO power

CONVERSION LOSS/SPURIOUS



TYPICAL OPERATING BANDS



RF	LO
6-8	10
8-10	12
10-12	14
12-14	10
14-16	12
16-18	14

SPECIFICATIONS - Model TBR0618HA1/TBR0618HA1-S

RF/LO Input Frequency Range	6 to 18 GHz
IF Output Frequency Range	0.05 to 5 GHz
Conversion Loss	6 dB Typical
Spurious	-55 dBc
Third Order Intercept Point	+23 dBm Typical
1 dB Compression Point	+13 dBm Typical

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For further information, please contact Mary Becker at (631) 439-9423 or e-mail mbecker@miteq.com

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AMPLIFIERS

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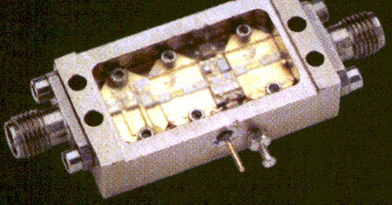
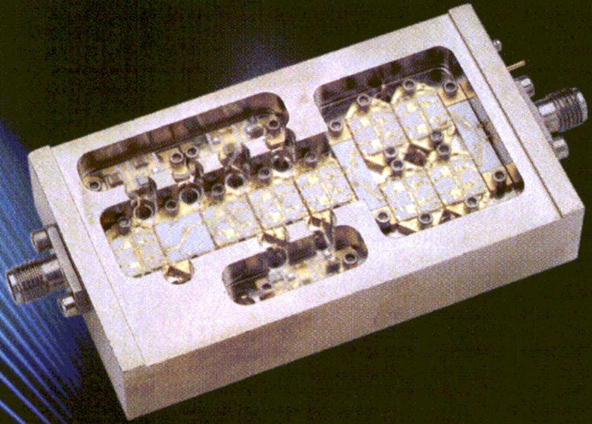


ULTRA BROAD BAND

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-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	Gain Flat +/-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

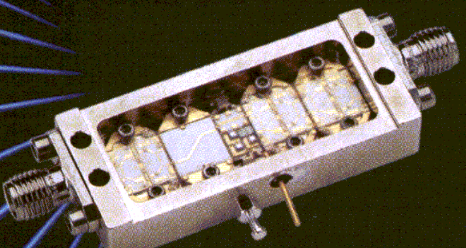


MEDIUM POWER AMPLIFIERS

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-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 OCTAVE BAND LNA'S

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-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



NARROW BAND LNA'S

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-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	1.2	0.5	13	23	1.5:1	150
JCA910-3001	9.5-10.0	25	1.2	0.5	13	23	1.5:1	150
JCA1112-3000	11.7-12.2	27	1.1	0.5	13	23	1.5:1	150
JCA1213-3001	12.2-12.7	25	1.1	0.5	10	20	2.0:1	200
JCA1415-3001	14.4-15.4	35	1.4	1.0	14	24	2.0:1	200
JCA1819-3001	18.1-18.6	25	1.8	0.5	10	20	2.0:1	200
JCA2021-3001	20.2-21.2	25	2.0	0.5	10	20	2.0:1	200

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DEFENSE ELECTRONICS for needs ranging from high power to high density. *Flexible* and *semi-rigid* products to withstand the severe conditions of shipboard, airborne or ground-based operations. A low-density PTFE dielectric *reduces attenuation* by up to 30% over conventional materials.

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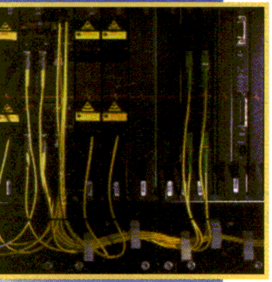
WIRELESS systems. The *outstanding thermal stability* of our semi-rigid products eliminates dielectric expansion during automated soldering processes.



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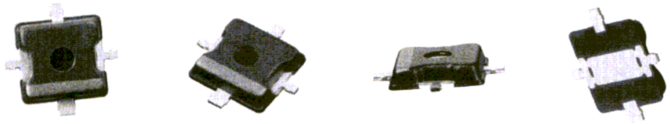

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- Small size: just 4.0 x 4.2 mm
- Large grounding pad for efficient heat dissipation

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- High output power, high linear gain and high efficiency.
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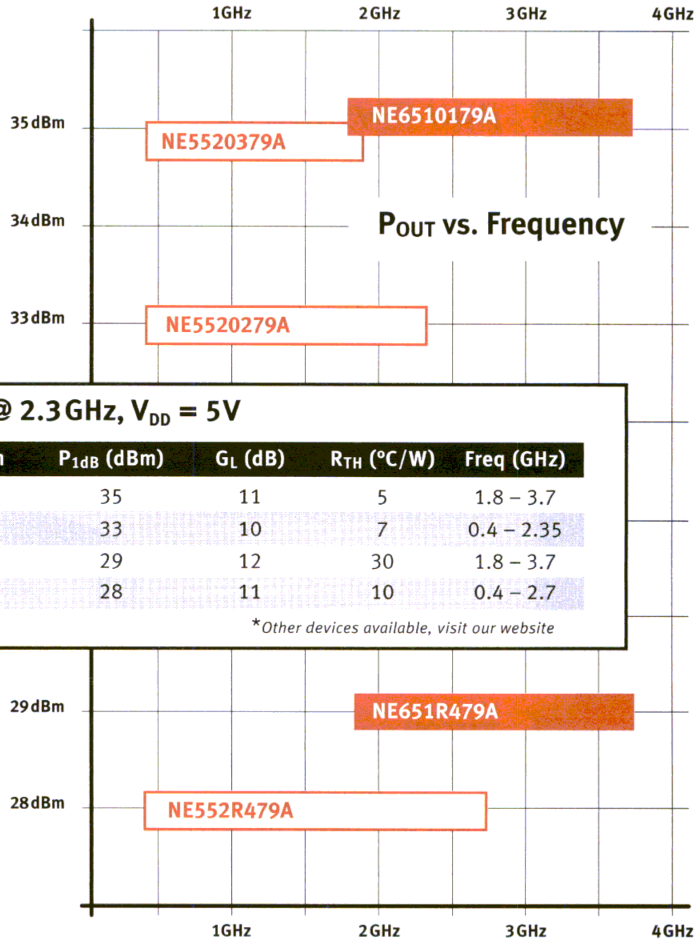

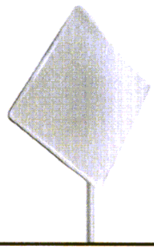

Typical Performance @ 2.3 GHz, V_{DD} = 5V

Part Number	Description	P_{1dB} (dBm)	G_L (dB)	R_{TH} (°C/W)	Freq (GHz)
NE6510179A	GaAs	35	11	5	1.8 – 3.7
NE5520279A	LDMOS	33	10	7	0.4 – 2.35
NE651R479A	GaAs	29	12	30	1.8 – 3.7
NE552R479A	LDMOS	28	11	10	0.4 – 2.7

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The Power in Broad Bandwidth Wireless Communications

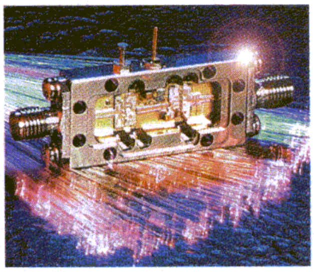
CTT Wireless announces optical driver amplifiers and subsystems for OC-192 communications.

Super Broadband Amplifiers for Fiber Optics

According to the Optoelectronics Industry Development Association, in 1999, component revenues for optoelectronic subsystem modules surpassed five billion dollars – with total revenues for all communication related opto-components at nearly thirty billion dollars.

Simplistically, network capacity can be increased by adding new fiber paths. Especially in metropolitan areas, installation costs and temporary service disruptions become prohibitive. One method of maximizing information density along a given single path (or fiber) is by transporting multiple channels on a single optical carrier or wave length through the technique of subcarrier multiplexing. In one such configuration, independent high-speed data streams are upconverted to microwave frequencies. The subcarriers are then combined into a complex waveform and then amplified with a CTT Wireless microwave amplifier.

CTT Wireless has developed a family of amplifiers for use in applications such as OC-192 (10 GB/S) as well as several other high-speed opto-applications up to 20 GB/S. Typical amplifier specifications include:



- 500 KHz to 20 GHz Freq. Range
- 18 db Gain
- Gain Flatness ±2.5 dB
- 10 dBm Power Output
- Single +12V Power Supply

To accommodate other optical modulation formats, CTT Wireless offers custom integration of amplifier (both narrowband and wide bandwidths), mixer, phase shift and attenuator functions in subsystem modules for performance up to 40 GHz.

Both amplifiers and subsystems incorporate CTT Wireless' latest high gain, low-noise modules. The MIC thin-film modules are eutechtically bonded to metal carriers within the housing, providing maximum efficiency and durability.

Our volume production ability has increasingly made CTT products the **hardware of choice** in the price-sensitive, **broad bandwidth**, **high linearity**, **wireless communications** market. This importance of choice, to the designer, is even more critical when understanding that CTT is providing RF functions that account for as much as one third the cost model in wireless communications base stations.

CTT's history, technical expertise, production know-how and resultant patronage allows the Company access to both monetary and production resources to excel in projects of any magnitude. At CTT Wireless we're committed to serving the wireless communications market with a simple goal: **Quality, Performance, Reliability, Service and On-Time Delivery of our products.**

To find out how we can provide you with the products and service, and cost-effective wireless solutions you are looking for, **contact CTT Wireless today.**

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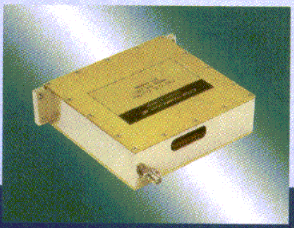


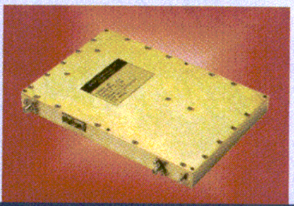
RUGGED FREQUENCY SYNTHESIZERS

A series of rugged frequency synthesizers designed for high capacity MW and MMW digital radios up to 38 GHz. With an emphasis on **Guaranteed Zero Phase Hits**™, the DFS Series offers extremely low microphonics and wide operating temperature range.

DC Power consumption below 4 watts is maintained by utilizing low power components resulting in low junction temperatures and overall high reliability.

SPECIFICATIONS

- **Frequency Range: 0.5-23 GHz**
- **Tuning Bandwidths up to 1000 MHz**
- **Switching Speed: <25 ms**
- **Phase noise meets 16, 32, 128 & 256 QAM requirements**
- **Output Power Range: 12-18 dBm**
- **Load VSWR 1.5:1**
- **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**
- **Fixed L-Band Output:**
  Freq. Range: 0.5-3.0 GHz
  Pwr. Out.: 12 dBm ±2 dBm
  Spurious: -95 dBc
- **Low Profile: 0.73" high**
- **Meets IESS, Eutelsat and MIL-STD-188/146**

PHASE LOCKED OSCILLATORS

The PDRO series of oscillators employ a unique technique to phase-lock DROs to a crystal reference of 5 to 100 MHz. Several models in the series require only a single loop for reliable phase-lock performance. By utilizing just one loop, size and power consumption are minimized and multiple frequencies can be realized from the same reference. The low profile and small size (2.5" x 3.5" x 0.65") features ultra low phase noise and low DC power consumption with a ruggedized design and wide operating temperature range.

SPECIFICATIONS

- **Frequency Range: 0.5-18 GHz**
- **Fractional Reference Multiplicator**
- **-100 dBc Spurious**
- **Meets MIL-STD-188 & IESS 308**
- **Integrated Reference Optional (Same Package)**

MINIATURE PHASE LOCKED OSCILLATORS

The miniature MPDRO sources employ a unique technology to phase-lock DRO to a crystal reference of 5 to 100 MHz. The technique requires only a single loop for reliable phase-lock performance. By using just one loop, size, power consumption and cost are minimized.

SPECIFICATIONS FOR THE MPDRO SERIES

- **0.5 to 26 GHz Operation**
- **Single Loop, locks to 5 to 100 MHz Reference**
- **Ultra Low Phase Noise**
- **Integrated Buffer Amplifier**
- **-100 dBc Spurious**
- **Ruggedized**
- **Low DC Power Consumption**
- **Small 2.25" x 1.4" x 0.8" Size**
- **Meets MIL-STD-188 and IESS 308**

Both the PDRO and MPDRO series of Phase Locked Oscillators are ideal for applications in Satcom Converters, Digital Radios and Instrumentation. In addition, the MPDRO series has applications as a fiber optic clock generator.

ADDITIONAL PRODUCTS PLANNED FOR ELCOM

- **Clock Encoders and Decoders for DWDM Fiber Optic Networks up to 40 GHz**
- **Synthesized Clock Generator for DWDM Fiber Optic Networks up to 40 GHz**
- **Clock Recovery Modules for DWDM Fiber Optic Networks up to 40 GHz**
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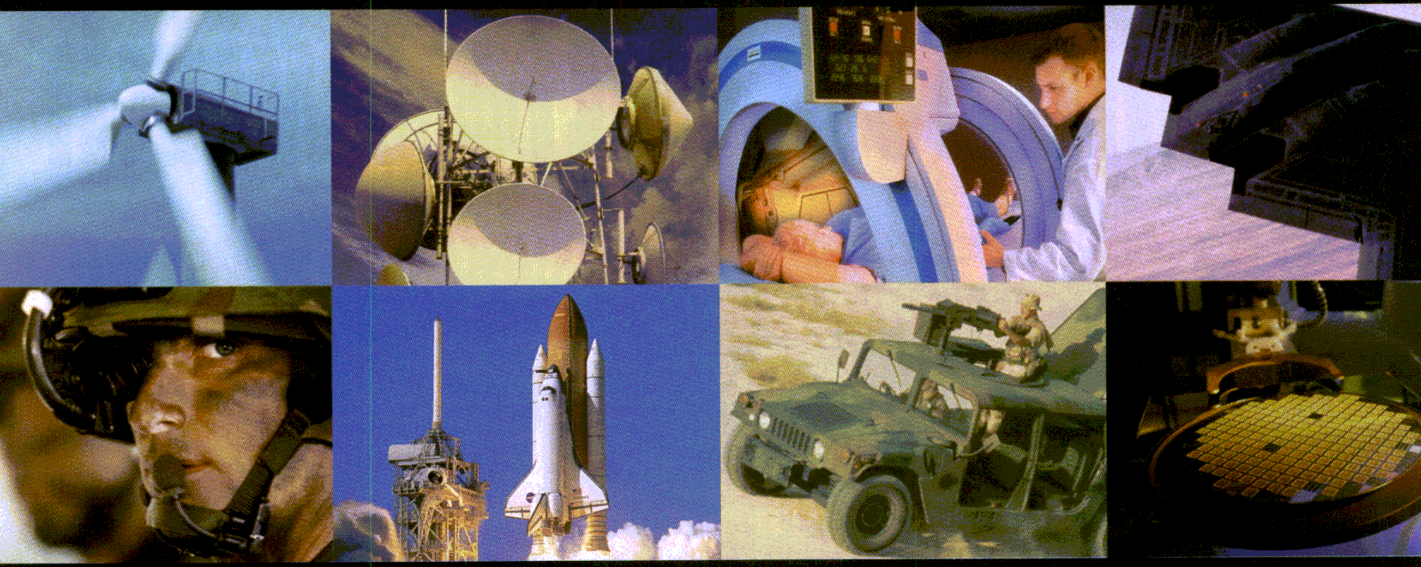


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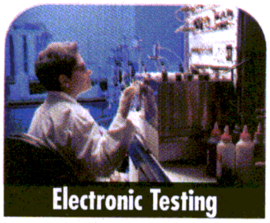

Correct Byline

I WOULD JUST like to point out that two byline misprints appeared in the May Cover Feature article "Compact Receive Module Shrinks CDMA Circuits" (May, p. 155) in *Microwaves & RF.*

The first thing is that Jim Hennessey's name is misspelled. It should appear as "Hennessey" and not as "Hennessy."

Also, Dr. Charles Wang and Robert Kincaid's job titles are incorrect. Dr. Charles Wang is a Senior Design Engineer and Robert Kincaid is a Design Engineer.

Eris Ball
RF Micro Devices

Contact Information

THE ARTICLE "RADIO Chip Sets Power Millimeter-Wave Systems" (June, p. 131) has some wrong contact information at the end of it. The correct phone number is (978) 664-8663. Also, the correct fax number is (978) 664-8646.

Pete Lentini
Raytheon RF Components

Editor's Note:

In the June article "Radio Chip Sets Power Millimeter-Wave Systems" there were several mistakes that appeared in addition to the wrong contact information, as noted in the previous letter.

In several instances throughout the article, numbers replaced plus or minus symbols, minus signs, or multiplication symbols.

Midway through the third paragraph, there is a sentence that reads "The RMWL26001 is a four-stage design that features 22-dB typical gain from 21 to 26.5 GHz with 61.4-dB...." The "6" in the decibel measurement should not be there. Instead, it should be a "±." This same symbol should also appear in the seventh paragraph which is on page 132 where it says "The amplifier provides 26-dB typical gain with 61-dB gain variation with frequency." Again, the "6" in this sentence should read "±." Similar types of sentences appear in the next two paragraphs (one in each paragraph). In both cases, the "6" should be "±."

In other instances, the number "2" replaces the "–" sign. This is seen in the last sentence of paragraph 3, toward the end. It is also mistakenly shown in the last sentence of paragraph 4, where it reads "220-dBm input power."

In the third paragraph from the end, "0.55-mm gate-length power GaAs PHEMT process" should read "0.55-µm gate-length power GaAs PHEMT process." Also in the same paragraph, the number "3" that is shown between the two measurements needs to be "×."

Our apologies to Raytheon and to our readers for these mistakes.

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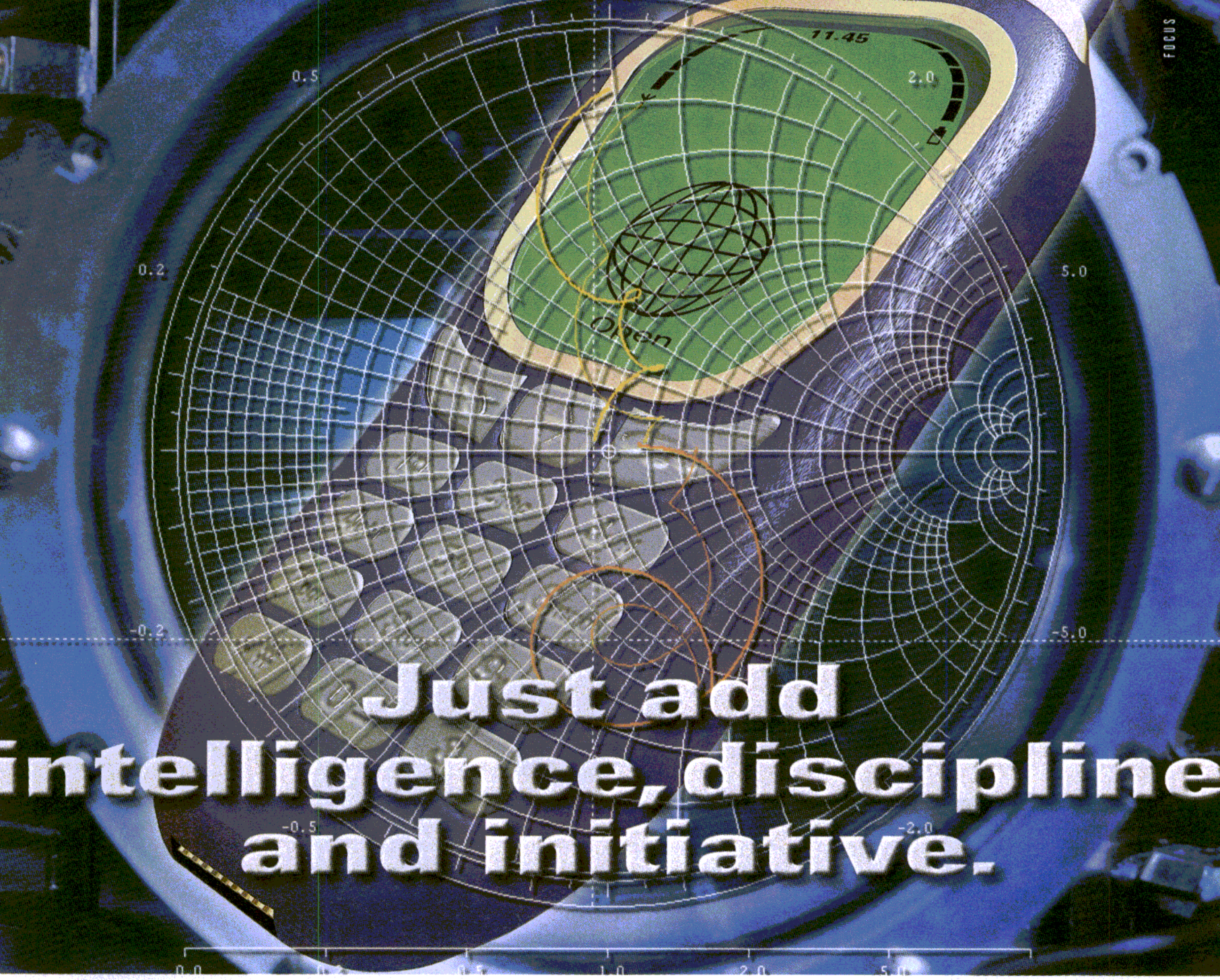
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Testing The Limits Of Millimeter Waves

Strangely, those who are involved in the design and development of millimeter-wave hardware and test equipment were seeing the most business activity.

DURING A RECENT swing through Northern California, it was apparent that the excitement and enthusiasm of the recent IEEE/International Microwave Theory & Techniques Symposium (MTT-S) conference and exhibition (May 20-25, 2001) was merely a short-term event. All that talk about the hard economic times possibly coming to an end by the third quarter of this year had been replaced by the reality—that no one knew when business would revive or, for that matter, even why it would revive. Most of the more than 30 companies visited during that week admitted that if they could achieve business goals that were flat compared to last year, they would consider the year a success.

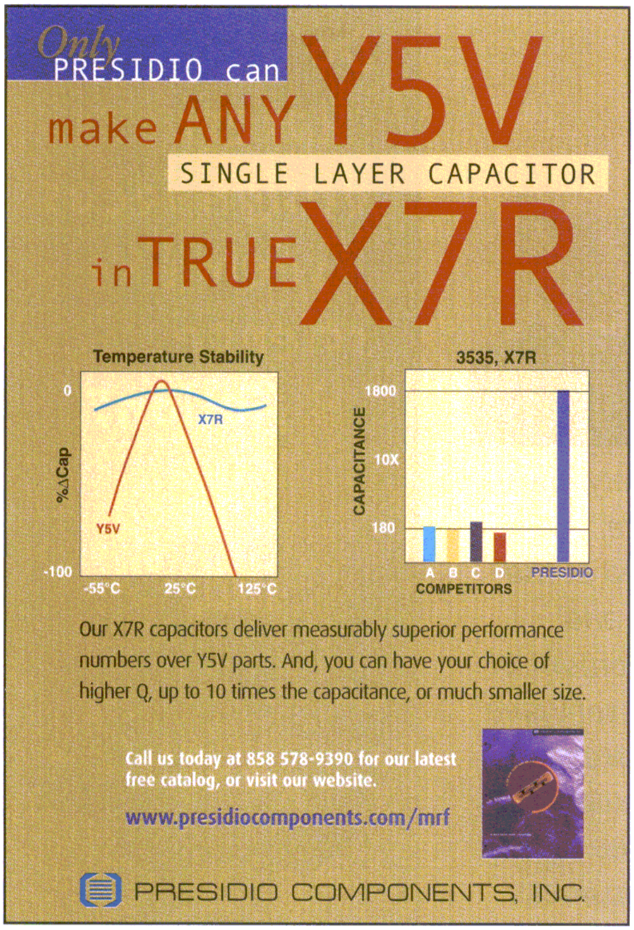
Yet, amidst the "doom and gloom" prognosticators stood those who were doing quite well, even during these challenging times. The most obvious healthy high-frequency/high-speed market in recent times has been in the design and manufacture of devices for analog and digital optical-communications systems.

Strangely, those involved in the design and development of millimeter-wave hardware and test equipment were seeing the most business activity, despite the harshness of the downturn for associates working with lower microwave and RF signals. Although these millimeter-wave markets are still a fraction of the size of markets at RF and microwave frequencies, large and small test-equipment suppliers are experiencing unprecedented demand for equipment at 38 GHz, 60 GHz, 77 GHz, and even 94 GHz. For example, Chuck Oleson of Oleson Microwave Labs (Morgan Hill, CA), is a true millimeter-wave designer for whom such things as 28-GHz LMDS applications might be considered at IF. Chuck, who designs and manufactures frequency extenders and other millimeter-wave test accessories for users and manufacturers of VNAs and other test instruments, has not experienced the economic downturn that has cursed many other small high-frequency-electronics companies.

Admittedly, the millimeter-wave market will likely never approach the magnitude promised by growth in optical communications. But there is much room for growth in the millimeter-wave market, especially if automatic applications take off and when more wireless bandwidths are consumed at lower frequencies. With the loss of lower-frequency bandwidths, there may be no choice but to use millimeter-wave bands.

Jack Browne

Publisher/Editor



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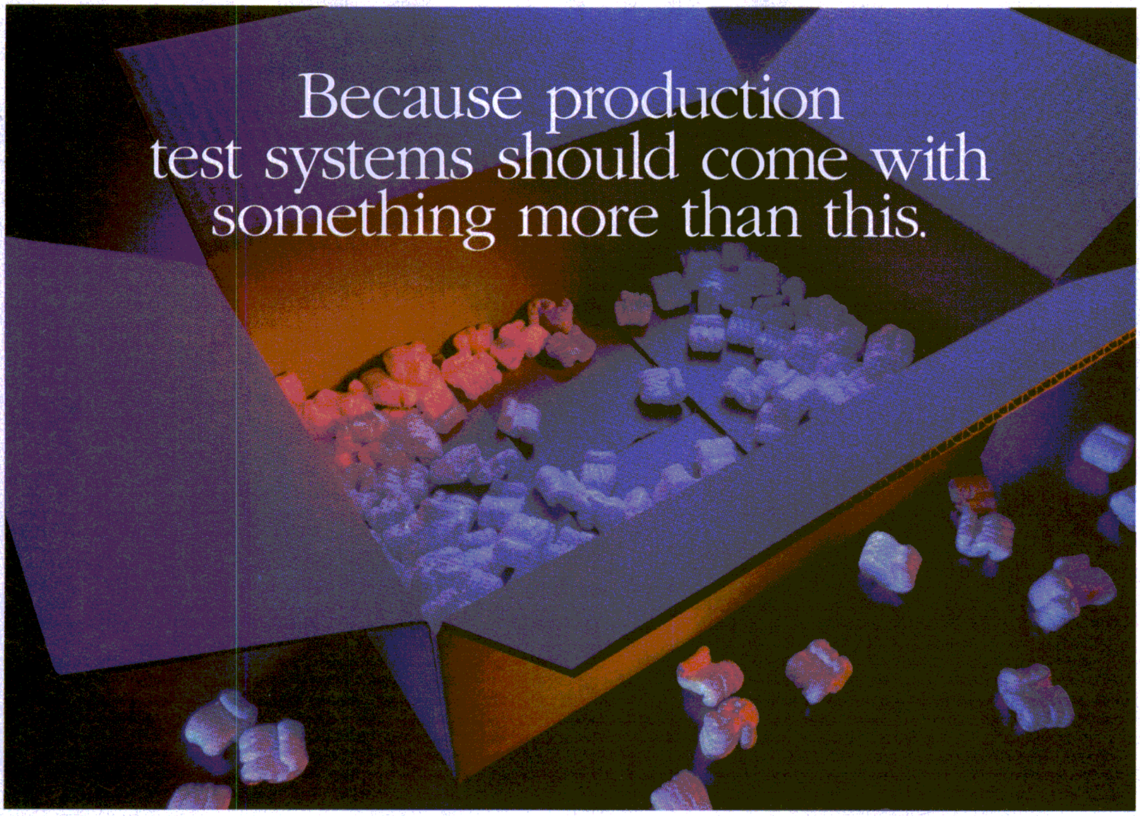
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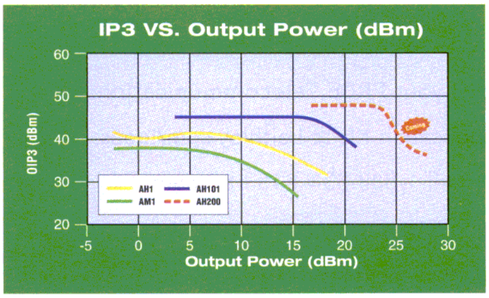

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AM1	250-3000	37	18	75
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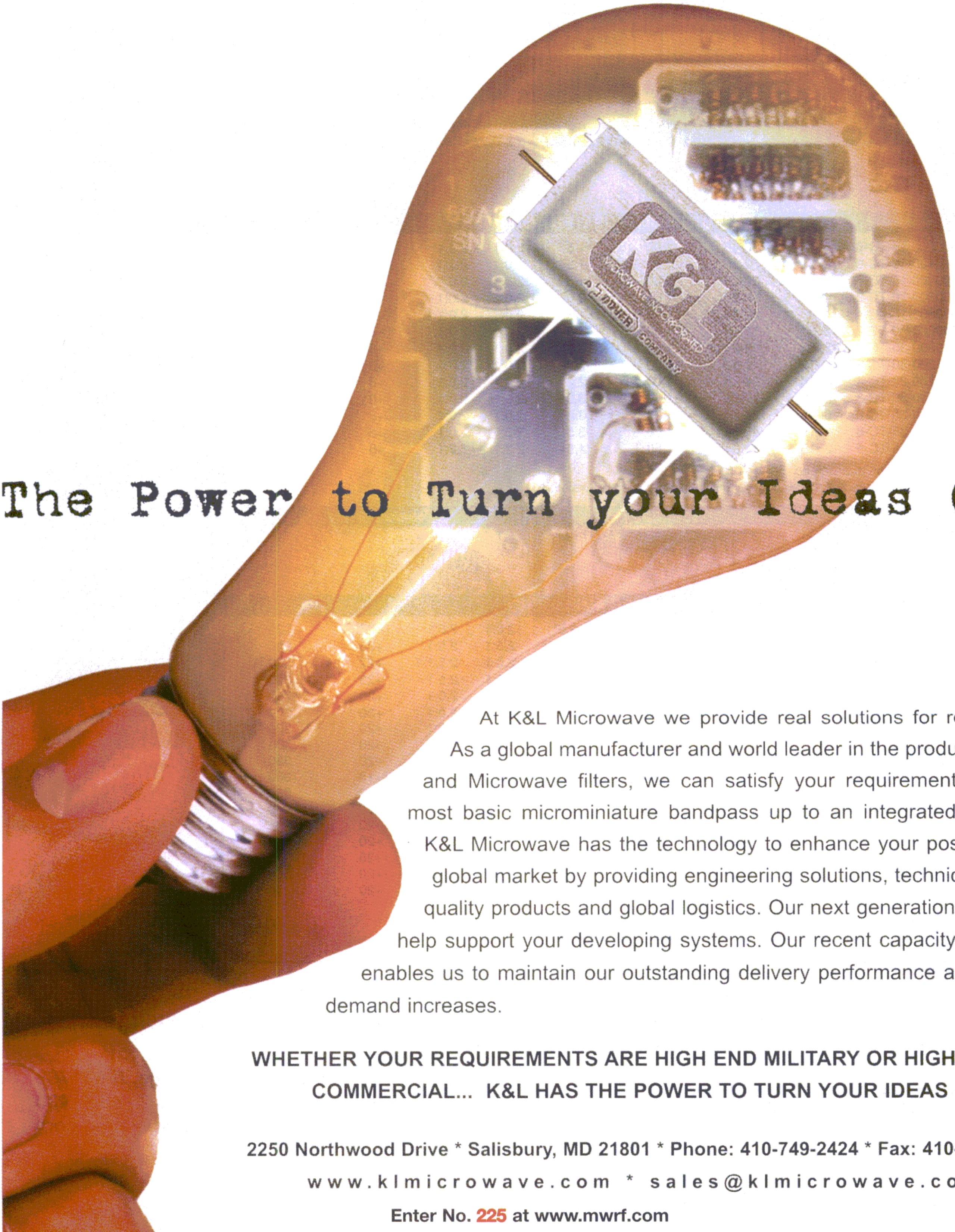

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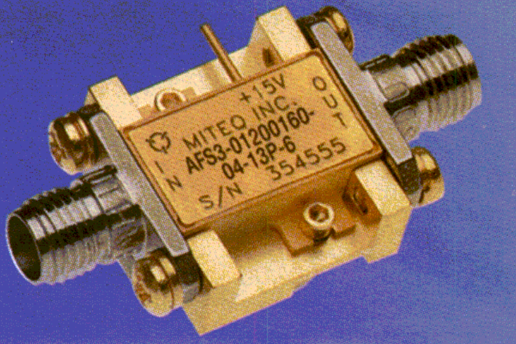

AMPLIFIERS

Model Number	Frequency Range (GHz)	Gain (Min./Max.) (dB)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	VSWR Input (Max.)	VSWR Output (Max.)	Output Power @ 1 dB Comp. (dBm, Min.)	Nom. DC Power (+15 V, mA)
TEMPERATURE COMPENSATED AMPLIFIERS								
AFS3-01000200-15-TC-6	1–2	36-40	1.00	1.5	2.0:1	2.0:1	+5	125
AFS2-02000400-15-TC-6	2–4	22-26	1.00	1.5	2.0:1	2.0:1	+5	125
AFS3-02000400-15-TC-6	2–4	22-26	1.00	1.5	2.0:1	2.0:1	+5	125
AFS2-04000800-20-TC-2	4–8	18-22	1.00	2.0	2.0:1	2.0:1	+5	100
AFS3-04000800-18-TC-4	4–8	26-30	1.00	1.8	2.0:1	2.0:1	+8	150
AFS2-02000800-40-TC-2	2–8	14-19	1.50	4.0	2.0:1	2.0:1	+5	100
AFS3-02000800-30-TC-4	2–8	22-27	1.50	3.0	2.0:1	2.2:1	+8	150
AFS2-08001200-30-TC-2	8–12	12-16	1.00	3.0	2.0:1	2.0:1	+5	100
AFS3-08001200-22-TC-4	8–12	24-28	1.00	2.2	2.0:1	2.0:1	+8	150
AFS4-12001800-30-TC-8	12–18	22-26	1.00	3.0	2.0:1	2.0:1	+8	250
AFS4-06001800-35-TC-6	6–18	22-26	1.00	3.5	2.0:1	2.0:1	+8	250
AFS6-06001800-35-TC-8	6–18	30-34	1.00	3.5	2.0:1	2.0:1	+8	400
AFS4-02001800-45-TC-5	2–18	18-24	1.50	4.5	2.2:1	2.2:1	+8	175

Note: All specifications guaranteed -54 to +85°C.
Many other frequencies, noise figures and gain windows are available.

Model Number	Frequency Range (GHz)	Gain (Min./Max.) (dB)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	VSWR Input (Max.)	VSWR Output (Max.)	Output Power @ 1 dB Comp. (dBm, Min.)	Nom. DC Power (+15 V, mA)
HIGHER POWER AMPLIFIERS								
AFS4-00050100-25-25P-6	0.5–2	36	1.50	2.5*	2.0:1	2.5:1	+25	325
AFS3-00100100-23-25P-6	.1–1	38	2.00	2.3	2.5:1	2.5:1	+25	280
AFS3-00100200-25-27P-6	.1–2	33	1.50	2.5	2.0:1	2.5:1	+27	300
AFS3-00100300-25-23P-6	.1–3	25	1.50	2.5	2.0:1	2.5:1	+23	300
AFS3-00100400-26-20P-4	.1–4	26	1.50	2.6	2.0:1	2.0:1	+20	250
AFS4-00100600-25-20P-4	.1–6	32	1.50	2.5	2.0:1	2.0:1	+20	300
AFS4-00100800-28-20P-4	.1–8	30	1.50	2.8	2.0:1	2.0:1	+20	300
AFS4-00101200-40-20P-4	.1–12	20	1.50	4.0	2.0:1	2.0:1	+20	300
AFS4-00501800-60-20P-6	.5–18	25	2.75	6.0	2.5:1	2.5:1	+20	350
AFS5-00102000-60-18P-6	.1–20	25	3.00	6.0	2.5:1	2.5:1	+18	360
AFS3-01000200-20-27P-6	1–2	33	1.50	2.0	2.0:1	2.0:1	+27	350
AFS3-02000400-30-25P-6	2–4	28	1.50	3.0	2.0:1	2.0:1	+25	250
AFS3-04000800-40-20P-4	4–8	20	1.00	4.0	2.0:1	2.0:1	+20	200
AFS4-08001200-50-20P-4	8–12	22	1.25	5.0	2.0:1	2.0:1	+20	200
AFS6-12001800-40-20P-6	12–18	28	2.00	4.0	2.0:1	2.0:1	+20	375
AFS6-06001800-50-20P-6	6–18	23	2.00	5.0	2.0:1	2.0:1	+20	365
AFS4-02001800-60-20P-6	2–18	23	2.50	6.0	2.5:1	2.0:1	+20	350

*Noise figure degrades below 100 MHz. Please consult factory for details.
Note: Noise figures increase below 500 MHz in bands wider than .1-10 GHz.

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Model Number	Frequency Range (GHz)	Gain (Min.) (dB)	Gain Flatness (±dB)	Noise Figure (dB, Max.)	VSWR Input (Max.)	VSWR Output (Max.)	Output Power @ 1 dB Comp. (dBm, Min.)	Nom. DC Power (+15 V, mA)
MODERATE BAND AMPLIFIERS								
AFS2-00700080-05-10P-4	.7–.8	30	0.50	0.45	1.5:1	1.5:1	+10	90
AFS2-00800100-05-10P-4	.8–1	30	0.50	0.45	1.5:1	1.5:1	+10	90
AFS3-01200160-05-13P-6	1.2–1.6	40	0.50	0.45	1.5:1	1.5:1	+13	150
AFS3-01400170-05-13P-6	1.4–1.7	40	0.50	0.45	1.5:1	1.5:1	+13	150
AFS3-01500180-04-13P-6	1.5–1.8	40	0.50	0.40	1.5:1	1.5:1	+13	150
AFS3-01500250-06-13P-6	1.5–2.5	36	0.50	0.60	2.0:1	2.0:1	+13	150
AFS3-01700190-04-13P-6	1.7–1.9	36	0.50	0.40	1.5:1	1.5:1	+13	150
AFS3-01800220-05-13P-6	1.8–2.2	36	0.50	0.50	1.5:1	1.5:1	+13	150
AFS3-02200230-04-13P-6	2.2–2.3	36	0.50	0.40	1.5:1	1.5:1	+13	150
AFS3-02300270-05-13P-6	2.3–2.7	34	0.50	0.45	1.5:1	1.5:1	+13	150
AFS3-02700290-05-13P-6	2.7–2.9	32	0.50	0.50	1.5:1	1.5:1	+13	150
AFS3-02900310-05-13P-6	2.9–3.1	32	0.50	0.45	1.5:1	1.5:1	+13	150
AFS3-03100350-06-10P-4	3.1–3.5	29	0.50	0.6	1.5:1	1.5:1	+10	150
AFS4-03400420-06-13P-6	3.4–4.2	40	0.50	0.60	1.5:1	1.5:1	+13	225
AFS3-04400510-07-5P-4	4.4–5.1	30	0.50	0.70	1.5:1	1.5:1	+5	100
AFS3-04500480-07-5P-4	4.5–4.8	30	0.50	0.70	1.5:1	1.5:1	+5	100
AFS3-05200600-07-5P-4	5.2–6	30	0.50	0.70	1.5:1	1.5:1	+5	100
AFS3-05400590-07-5P-4	5.4–5.9	30	0.50	0.70	1.5:1	1.5:1	+5	100
AFS3-05800670-07-5P-4	5.8–6.7	30	0.50	0.70	1.5:1	1.5:1	+5	100
AFS3-07250775-06-5P-4	7.25–7.75	30	0.50	0.60	1.5:1	1.5:1	+5	100
AFS3-07900840-07-5P-4	7.9–8.4	30	0.50	0.70	1.5:1	1.5:1	+5	100
AFS4-08500960-08-5P-4	8.5–9.6	32	0.75	0.80	1.5:1	1.5:1	+5	125
AFS3-09001100-09-5P-4	9–11	26	0.50	0.90	1.5:1	1.5:1	+5	100
AFS4-09001100-09-5P-4	9–11	32	0.75	0.90	1.5:1	1.5:1	+5	125
AFS4-10951175-09-5P-4	10.95–11.75	32	0.75	0.90	1.5:1	1.5:1	+5	125
AFS4-11701220-09-5P-4	11.7–12.2	32	0.75	0.90	1.5:1	1.5:1	+5	125
AFS2-12201280-10-8P-4	12.2–12.8	14	0.75	1.00	1.5:1	1.5:1	+8	80
AFS4-12201280-10-12P-4	12.2–12.8	27	0.75	1.00	1.5:1	1.5:1	+12	200
AFS4-12701330-13-10P-4	12.7–13.3	27	0.75	1.30	1.5:1	1.5:1	+10	175
AFS4-13201400-14-10P-4	13.2–14	24	0.75	1.40	1.5:1	1.5:1	+10	175
AFS4-14001450-14-10P-4	14–14.5	24	0.75	1.40	1.5:1	1.5:1	+10	175
AFS4-20202120-20-8P-4	20.2–21.2	20	1.00	2.00	1.5:1	1.5:1	+8	175
AFS4-21202400-22-10P-4	21.2–24	18	1.00	2.2	2.0:1	2.0:1	+10	100
OCTAVE BAND AMPLIFIERS								
AFS3-00120025-09-10P-4	.12–.25	38	0.50	0.9	2.0:1	2.0:1	+10	175
AFS3-00250050-08-10P-4	.25–.5	38	0.50	0.8	2.0:1	2.0:1	+10	125
AFS3-00500100-05-10P-6	.5–1	38	0.75	0.5	2.0:1	2.0:1	+10	150
AFS3-01000200-05-10P-6	1–2	38	1.00	0.5	2.0:1	2.0:1	+10	150
AFS3-01200240-05-10P-6	1.2–2.4	34	1.00	0.5	2.0:1	2.0:1	+10	175
AFS3-02000400-06-10P-4	2–4	30	1.00	0.6	2.0:1	2.0:1	+10	125
AFS3-02600520-10-10P-4	2.6–5.2	28	1.00	1.0	2.0:1	2.0:1	+10	150
AFS3-04000800-07-10P-4	4–8	30	1.00	0.7	2.0:1	2.0:1	+10	125
AFS3-08001200-09-10P-4	8–12	26	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-08001600-15-8P-4	8–16	26	1.00	1.5	2.0:1	2.0:1	+8	80
AFS4-12002400-25-10P-4	12–24	20	2.00	2.5	2.0:1	2.0:1	+10	85
AFS4-12001800-18-10P-4	12–18	26	1.00	1.8	2.0:1	2.0:1	+10	125
AFS4-18002650-28-8P-4	18–26.5	18	1.75	2.8	2.5:1	2.2:1	+8	150
MULTIOCTAVE BAND AMPLIFIERS								
AFS1-00040200-12-10P-4	.04–2	15	1.50	1.2	2.5:1	2.0:1	+10	75
AFS3-00300140-08-10P-4	.3–1.4	33	1.00	0.8	2.0:1	2.0:1	+10	150
AFS2-00400350-12-10P-4	.4–3.5	22	1.50	1.2	2.0:1	2.0:1	+10	80
AFS3-00500200-08-15P-4	.5–2	38	1.00	0.8	2.0:1	2.0:1	+15	125
AFS3-01000400-09-10P-4	1–4	30	1.50	0.9	2.0:1	2.0:1	+10	125
AFS3-02000800-09-10P-4	2–8	26	1.00	0.9	2.0:1	2.0:1	+10	125
AFS4-02001800-23-10P-4	2–18	25	2.00	2.3	2.0:1	2.0:1	+10	175
AFS4-06001800-22-10P-4	6–18	24	2.00	2.2	2.0:1	2.0:1	+10	150
AFS4-08001800-22-10P-4	8–18	26	2.00	2.2	2.0:1	2.0:1	+10	150
ULTRA WIDEBAND AMPLIFIERS								
AFS3-00100100-09-10P-4	.1–1	38	1.00	0.9	2.0:1	2.0:1	+10	150
AFS3-00100200-10-15P-4	.1–2	38	1.00	1.0	2.0:1	2.0:1	+15	150
AFS3-00100300-11-10P-4	.1–3	32	1.00	1.1	2.0:1	2.0:1	+10	150
AFS3-00100400-13-10P-4	.1–4	28	1.00	1.3	2.0:1	2.0:1	+10	150
AFS3-00100600-13-10P-4	.1–6	28	1.25	1.3	2.0:1	2.0:1	+10	125
AFS3-00100800-14-10P-4	.1–8	25	1.50	1.4	2.0:1	2.0:1	+10	125
AFS4-00101200-22-10P-4	.1–12	28	1.50	2.2	2.0:1	2.0:1	+10	175
AFS4-00101400-23-10P-4	.1–14	24	2.00	2.3	2.5:1	2.5:1	+10	200
AFS4-00101800-25-10P-4	.1–18	25	2.00	2.5	2.5:1	2.5:1	+10	175
AFS4-00102000-30-10P-4	.1–20	20	2.50	3.0	2.5:1	2.5:1	+10	175
AFS4-00102650-40-8P-4	.1–26.5	18	2.50	4.0	2.5:1	2.5:1	+8	175

Note: Noise figure increases below 500 MHz in bands greater than 0.1-10 GHz.

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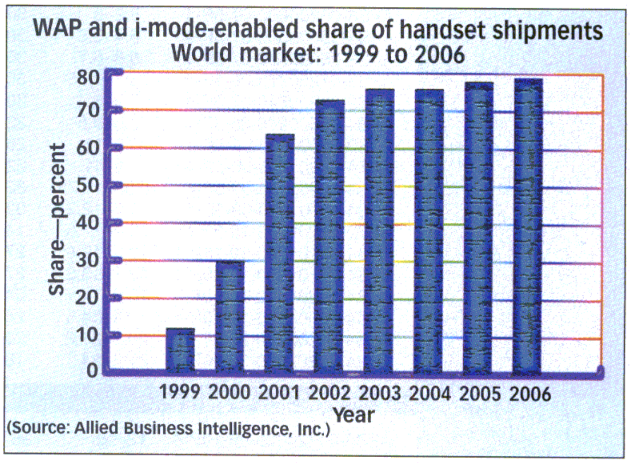
News items from the communications arena.

3G, Wireless Internet Will Drive Wireless Handset And PDA Sales

OYSTER BAY, NY—The wireless Internet has begun to establish a new market for wireless handsets, personal digital assistants (PDAs), laptops, and other wireless clients, as wireless operators begin to deploy high-speed data services in mobile networks worldwide.

According to the findings in the study "Wireless Portable Devices: World Market for 2G, 2.5G and 3G Devices and Connectivity to the Wireless Internet," data-enabled handsets using wireless-application protocol (WAP) and i-mode, or a combination of the two, will account for 80 percent of the handsets shipped in 2006, up from 30 percent in 2000 **(see figure)**. Handsets using two-and-a-half-generation (2.5G) or third-generation (3G) technology will rise to more than half of all handsets shipped in 2006, with wideband code-division multiple access (WCDMA) having the largest share of the group.



WAP and i-mode-enabled share of handset shipments World market: 1999 to 2006

(Source: Allied Business Intelligence, Inc.)

"The wireless handset shipments were not that poor in 2000 and actually met ABI's forecast," says Allied Business Intelligence, Inc. (ABI) senior vice president Larry Swasey, the report's author. "The wireless handset market could not grow as greatly as many expected, since there were few new services introduced and the wireless handset basically remained a voice tool for the most part. But in 2000 there was still a decent rise in handset shipments."

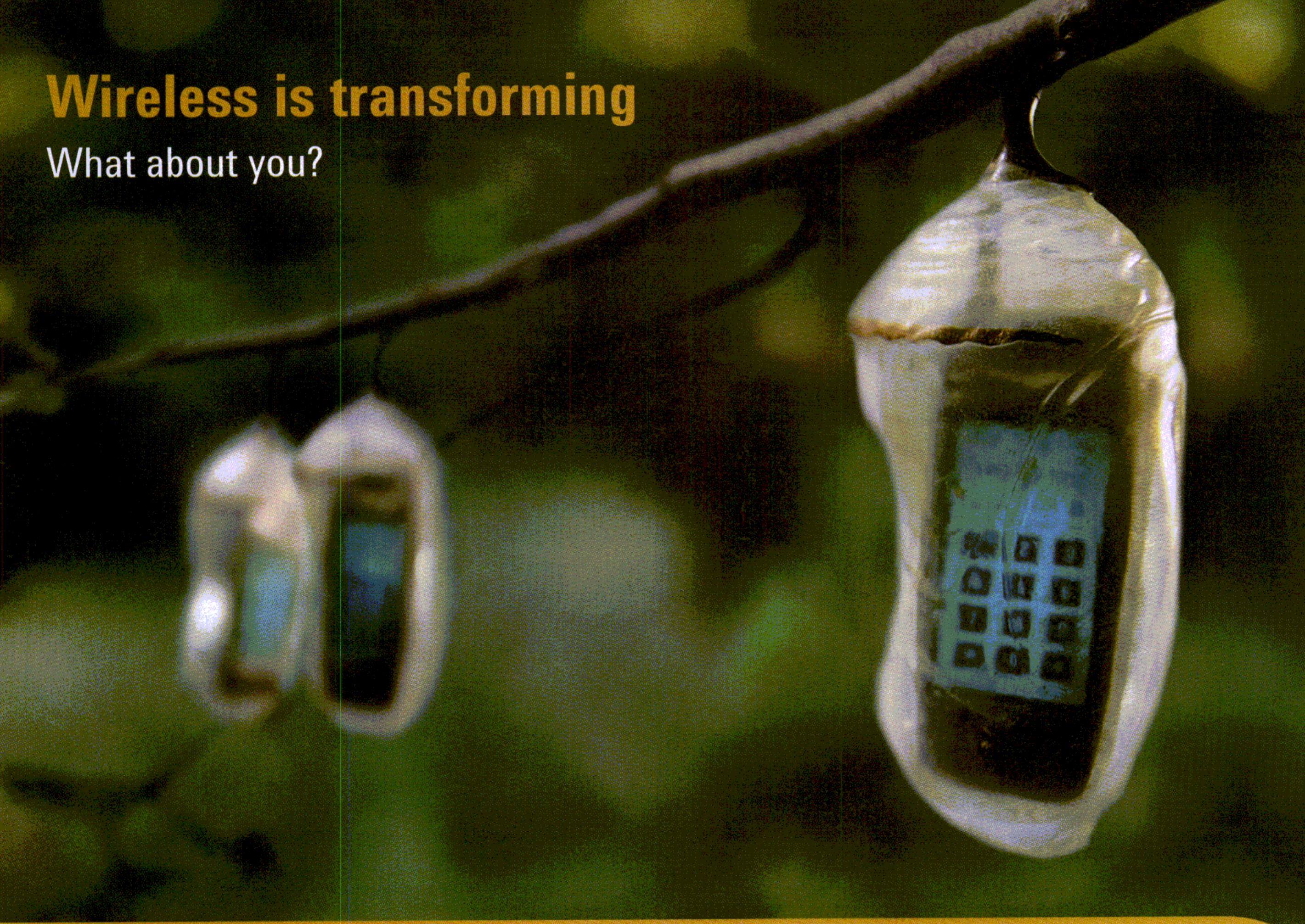
Bluetooth will also play a large role in wireless connectivity, with more than 90 percent of all handsets shipped incorporating Bluetooth by 2006.

Two-Chip WLAN Solution Is Introduced

IRVINE, CA—Intersil Corp., a developer of silicon (Si) technology for wireless local-area networks (WLANs), recently announced details of its next-generation PRISM® WLAN chip-set solution. PRISM 3 incorporates a Zero-IF (ZIF) architecture which supports what is known as "direct downconversion" of RF signals, enabling low-cost, high-performance wireless networking solutions that target consumer applications.

The PRISM 3 chip set is comprised of two highly integrated circuits, one of which is a direct-downconversion (DDC) transceiver. This device takes high-frequency radio waves and directly converts them to the baseband signal during reception, or directly upconverts them from the low-level baseband signal to RF during transmission. This new architecture eliminates the need for the usual intermediate-frequency (IF) stage found in most radios, thereby reducing complexity, bill-of-materials (BOM) cost, and manufacturing cost. The DDC transceiver couples to the second IC in the chip set, a baseband processor/medium-access controller (BBP/MAC). The tight coupling of the radio front end with this processor overcomes DC offset problems normally associated with ZIF radios.

"The PRISM 3 chip set represents a significant technical achievement and is a revolutionary step in our product roadmap," says Larry Ciaccia, vice president and GM of PRISM Wireless Products at Intersil. "It's the world's first complete WLAN direct-downconversion chip set designed from the ground up to catalyze the consumer market for high-speed wireless connectivity."



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RF Technology Enables Mobile Antennas To Operate Using Any Frequency

SAN DIEGO, CA—The Titan Corp. and its subsidiary, e-tenna Corp., a developer of RF technologies, unveiled a technology to enable phones to pick up radio signals of any technology within any frequency range, thus allowing seamless international service.

While current approaches to building handsets that support multimode and multistandard operations result in increased complexity, a greater number of components, and higher manufacturing costs, e-tenna's Radio Frequency to Intermediate Frequency (RF2IF) technology reduces complexity by consolidating the front end of a wireless phone. By integrating features such as diplexers, filters, switches, and even the antenna itself in a unique way, RF2IF may reduce antenna manufacturers' costs up to 20 percent. In addition, RF2IF incorporates new components within the device's circuitry that enable the RF side of the phone to reconfigure, or dynamically adapt to, the frequency range and technology in which it is operating.

"While many companies have focused their efforts on developing software or digital circuitry that enable radios to operate in multiple modes, a critical aspect remains to be addressed: the RF portion of the phone. Reworking RF design is critical to making software-defined radios (SDRs) work," says Lee Stein, chairman and CEO of e-tenna. "e-tenna's RF2IF technology focuses on enabling one single RF module to support several technologies and frequencies and, thus, several applications — from voice services to 2.5G and 3G data services to Bluetooth."

> *"While many companies have focused their efforts on developing software or digital circuitry that enable radios to operate in multiple modes, a critical aspect remains to be addressed: the RF portion of the phone."*

Wireless Research And Teaching Center Is Established

LOGAN, UT—Utah State University has embarked on a new educational venture, to explore wireless technology. The Richard and Moonyeen Anderson Wireless Research and Teaching Center has been founded for that purpose.

Cynthia Furse, associate professor of electrical and computer engineering at Utah State, will direct the center, which is located in Lab EL-255 of the Dean F. Peterson Engineering Building on the USU campus. The center officially opened with a ribbon-cutting ceremony on May 2. Among the center's objectives are providing opportunities for undergraduate and graduate students to explore diverse medical, agricultural, and industrial applications for wireless technology through hands-on projects.

"The timing for the center couldn't be better," comments Furse. "Wireless communication is exploding faster than any other technology we've seen — even silicon computer chips."

Furse added that the project fits perfectly with Governor Leavitt's engineering and technology initiative, which includes building a tech-savvy workforce and raising Utah's profile within the high-tech community.

The center is the brainchild of USU alumnus Richard Anderson who retired four years ago from a 38-year telecommunications career with Hewlett-Packard. Anderson and his wife, Moonyeen, donated more than $1 million to the project, the largest single cash donation in the College of engineering's history.

RADAR Flashlight Aids Police In Search For Suspects

ATLANTA, GA—Law-enforcement officers serving a warrant or searching for a suspect hiding inside a building could soon have a new tool for protecting themselves and locating the suspect.

A prototype device known as the RADAR Flashlight, developed at the Georgia Tech Research Institute (GTRI), can detect a human's presence through doors and walls up to 8 in. (20.32 cm) thick. The device uses a narrow 16-deg. radar beam and specialized signal processor to discern respiration and/or movement up to 3 m behind a wall. The device can penetrate even heavy clothing to detect respiration and movements of as little as a few millimeters.

"We believe the RADAR Flashlight will be useful to police officers in ambush situations," says Gene Greneker, the GTRI principal research scientist who led the development of the device.

The RADAR Flashlight is undergoing further modification and testing for the next three months. The Georgia Institute of Technology has filed a provisional patent for the device, which could become commercially available to law-enforcement officials within a couple of years if the university licenses the technology to a manufacturer.

Strategic Alliance For Chip Manufacturing Is Announced

ALLENTOWN, PA AND GREENSBORO, NC—Agere Systems and RF Micro Devices, Inc. announced that they have signed definitive agreements to form a strategic alliance to develop, design, and manufacture chips for next-generation, data-capable digital cellular phones and other communications products.

Under one part of the agreement, RF Micro Devices will invest approximately $58 million over two years to upgrade manufacturing cleanroom space and purchase semiconductor-manufacturing equipment, which will be deployed within Agere's Orlando, FL manufacturing facility. RF Micro Devices anticipates no significant impact on fiscal year 2002 earnings, and capital expenditures related to the alliance have already been included in previous guidance for fiscal year 2002. Production from the purchased equipment will be allocated first to RF Micro Devices and then to Agere, thereby providing silicon (Si) capacity to RF Micro Devices while providing both companies with the benefits of combined operations and increased manufacturing volumes. RF Micro Devices plans to deploy Si manufacturing engineers in Orlando, FL as part of the alliance.

Agere Systems and RF Micro Devices will work together on a class of RF chips. These RF chips will be based primarily on an emerging semiconductor-materials technology known as silicon germanium (SiGe), which has excellent performance characteristics for certain wireless applications and can be economically produced using widely available Si integrated-circuit (IC) processing equipment and techniques. The alliance will also encompass Agere's other Si processes.

> *"Wireless communication is exploding faster than any other technology we've seen—even silicon computer chips."*

Moonbounce Beacon Has Become Operational

LITTLE FERRY, NJ—The SETI League, Inc., an organization involved in the privatized Search for Extra-Terrestrial Intelligence, has placed a transmitter (Tx) on the air that bounces microwave signals off the surface of the Moon, for use in testing Earth-based radio telescopes. The American Astronomical Society provided financial assistance for the project.

Operating under the callsign W2ETI at an allocated amateur RF of 1296 MHz, the EME (Earth-Moon-Earth) beacon enables amateur and professional radio astronomers alike to calibrate their receiving systems by providing a stable reference signal emanating from a known point in the sky.

The SETI League's EME beacon received its first shakedown in March, providing scientists at the Arecibo Observatory in Puerto Rico with a weak, well-calibrated test signal for use in conjunction with the Project Phoenix-targeted search for extraterrestrial intelligence.

Kudos

Antenna Specialists, a division of Allen Telecom, Inc., announced that its chief antenna engineer, James Hadzoglou, has been awarded US Patent No. 6,215,451 B1 as of April 10, 2001 for technology used in dual-band "On-Glass" antennas at cellular (824-to-894-MHz) and personal-communications-services (PCS) frequencies, as well as adjacent frequency bands...D. Canon Bradley was presented with the David P. Larsen Award in Seattle, WA during the 2001 IEEE International Frequency Control Symposium and PDA Exhibition. He received the award for his many years of dedication and engineering contributions to the industry. Bradley has just completed three terms as chairman of the industry's international technical-standards committee...Agilent Technologies, Inc. announced that its miniature film-bulk-acoustic-resonator (FBAR) duplexer has earned a 2000 Technology Award from *Wireless Design & Development Magazine*...Mobilestar Network Corp. has been awarded the 2001 CMP Media LLC's Network Computing Well-Connected Award. MobileStar received highest honors in the category of Most Innovative New Wireless Data Service at a ceremony held on May 7 during Networld + Interop 2001 in Las Vegas, NV...Zeevo, Inc. announced that its TC2000™ single-chip baseband, link manager, and associated software have been granted 1.1 Bluetooth qualification and are now updated on the Bluetooth Qualified Product List (BQPL)...Sprint has donated its broadband fixed wireless service, Sprint Broadband Direct℠, to Eastside College Preparatory School in East Palo Alto, CA. The service, which provides download speeds of up to 50 times faster than traditional dial-up modems, will provide high-speed Internet access to the computer lab at Eastside. MRF

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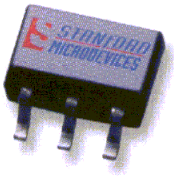
Stanford Microdevices' SGL Series silicon-germanium (SiGe) amplifiers offer the wireless system designer noise figures typical of GaAs devices at silicon prices.



SOT-363 Package

And, their economy goes beyond price. Low noise figure makes them ideal for today's vast range of wireless devices. These units also offer exceptional Input IP3 performance for the DC power consumed at 3 volts. At the designer's option, P1dB and Input IP3 can be increased 5 dB by operating with a 4-volt device voltage.

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Part Number	Freq Range (MHz)	Vd (V)	Id (mA)	P1dB (dBm)	Input IP3 (dBm)	Gain @ (dB)	NF 50 ohm (dB)	Package
SGL-0163	800-1000	3.0	11	+5	+6	15	1.1	SOT-363
SGL-0263	1800-2500	3.0	11	+5	+7	14	1.3	SOT-363

Gain and Input IP3 can be increased 5 dB with a 4.0 device voltage, 25 mA.

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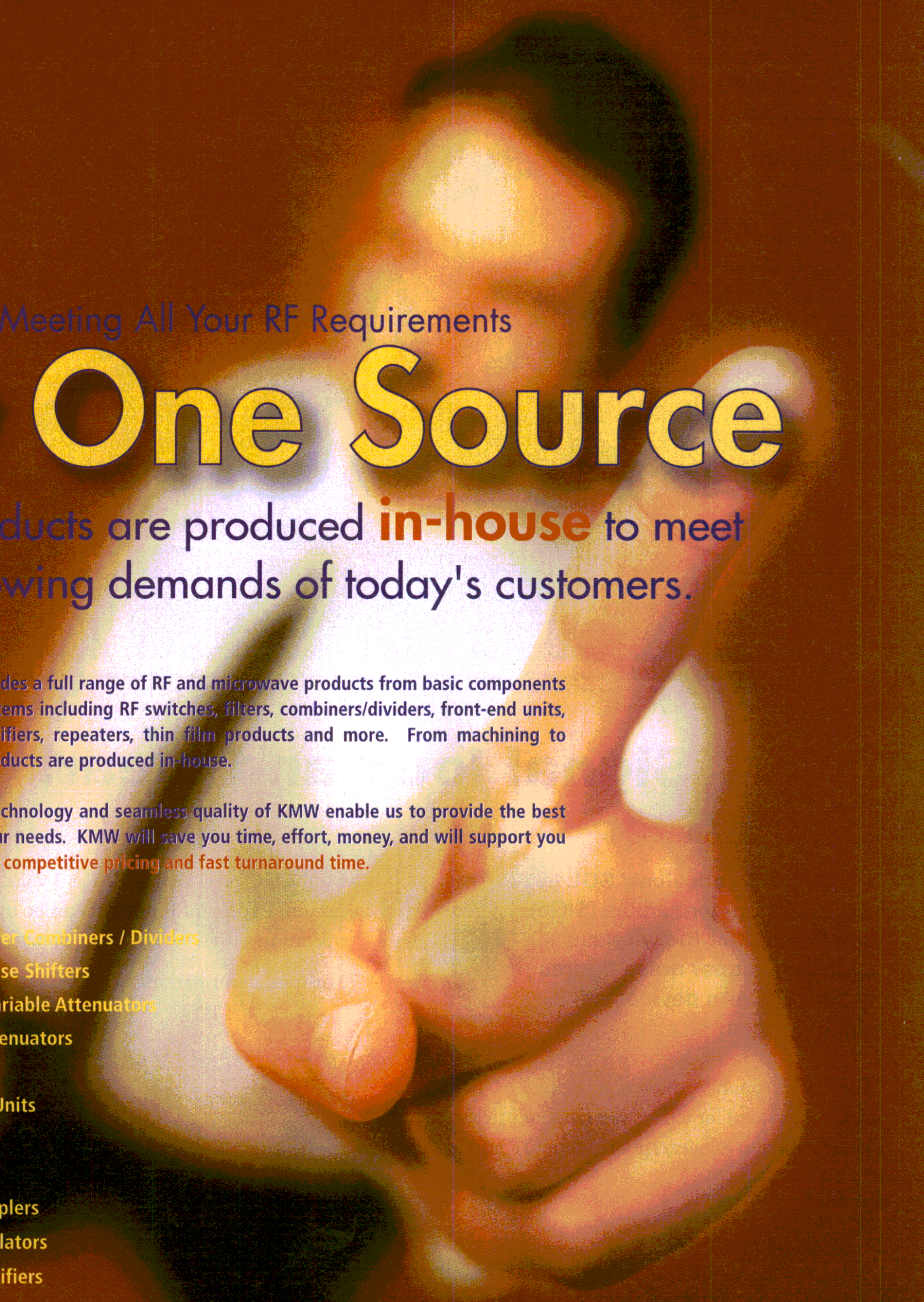

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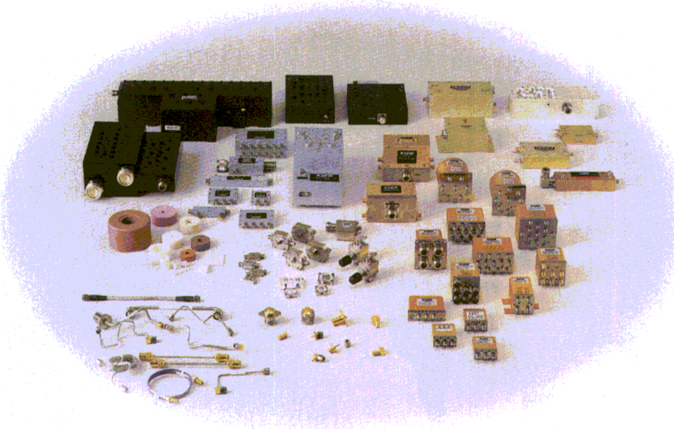

Switchable Power Combiners / Dividers
Contactless Phase Shifters
Continuously Variable Attenuators
Step-Rotary Attenuators
RF Switches
Filters
Power Splitters
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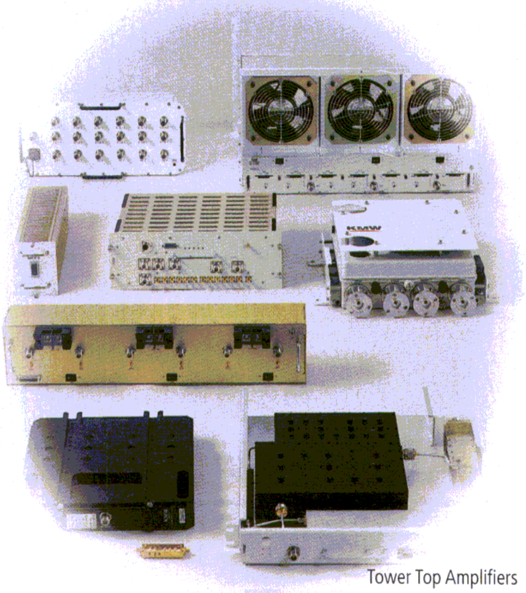
Circulators / Isolators
Connectors & Cable Assemblies
Ceramics & Thin Film Products



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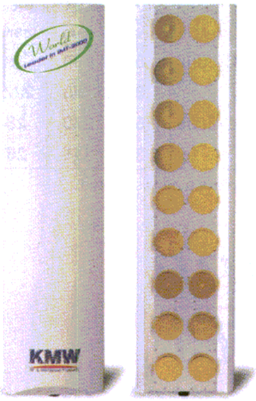

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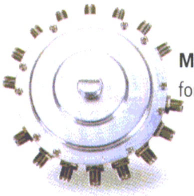

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Part Number	Frequency Range (MHz)	Device Voltage (V)	Id (mA)	P1dB (dBm)	IP3 (dBm)	Gain @ 1 GHz (dB)	Gain @ 2 GHz (dB))	NF @ 1 GHz (dB)
SGA-9189	**DC-3000**	**5**	**180**	**26**	**39**	**18**	**12**	**2.5**
		3	**165**	**22.5**	**35**	**18**	**12**	**2.2**
SGA-9289	**DC-3000**	**5**	**270**	**28**	**41**	**18**	**11**	**2.9**
		3	**315**	**26**	**39**	**17**	**11**	**2.6**

*Data at 2 GHz unless otherwise noted

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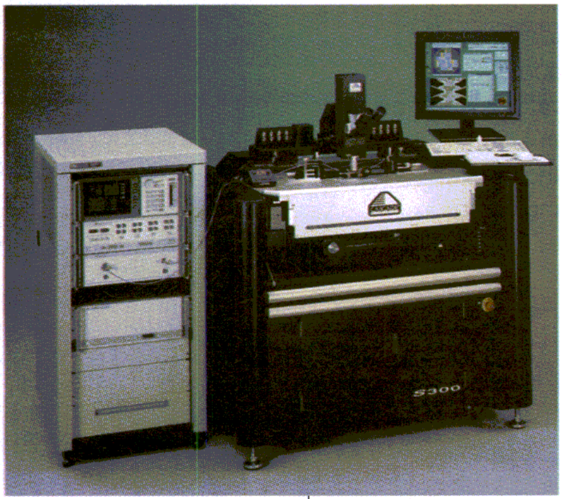
T&M Firms Forge Ahead Despite The Communications Slump

Test-and-measurement manufacturers continue to push new products in the face of a sharp downturn in the communications industry.

GENE HEFTMAN
Senior Editor

For the past year, the communications industry has taken a miserable pounding as financial problems among the telecommunications giants have spread up and down the food chain of suppliers to the industry. Test-and-measurement (T&M) companies have not been immune to the economic turmoil, but some of them have generally fared better than companies in the industry. Those that are performing well are doing so because they serve a part of the communications industry that is weathering the storm better than most sectors. Not only that, but T&M manufacturers have an abiding conviction that the high-technology express is merely stalled and not derailed. The road to recovery, according to industry executives, lies in not panicking, but sticking to one's game plan and continually going down the path of new product development. Another viewpoint on the general high-technology environment in the US can be found in "Is The Hi-Tech Boom Over," on page 50 of this issue.



1. Test equipment, such as the S300 RF/microwave probing system from Cascade Microtech, performs accurate measurements on semiconductor wafers that will be used for next-generation communications products.

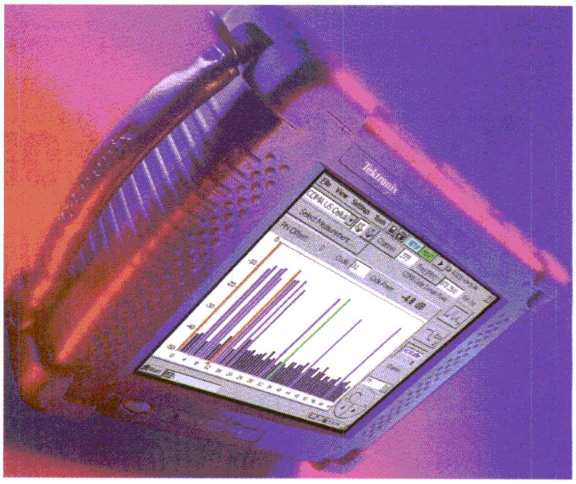
One T&M company that claims a minimal impact from the communications downturn is LeCroy (Chestnut Ridge, NY), best known for its high-performance digital oscilloscopes and power-measurement systems. Through the first three quarters of the year, the company is ahead in revenues and profits. What is the key to LeCroy's success in this weak market? According to Mike Lauterbach, Director of Product Management, "The big slowdown in the telecommunications market is in infrastructure deployment, and LeCroy is not tightly coupled to the manufacturing end. We are more tied into research and development (R&D)."

Being on the R&D side of the communications business and away from the nuts and bolts seems to be one of the important factors in maintaining a healthy bottom line during hard times. T&M companies whose instruments are needed by project designers can profit since, "across the industry, engineering projects are generally funded at the long-term growth rate of the segment, in spite of cyclical surges or drops in revenue," says Eric Strid, CEO of Cascade Microtech, Inc. (Beaverton, OR). His company manufactures on-wafer test systems and production probe cards used in manufacturing and R&D of integrated circuits (ICs).

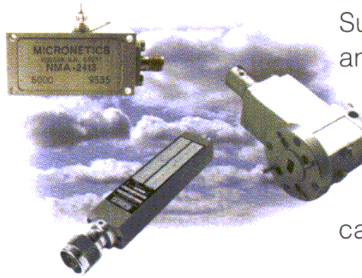
The industry's weakness lies primarily in the manufacturing sector and Strid says that production tool vendors are "at the tail of the whip—when system sales flatten out, components drop, and production equipment shuts off. Net bookings of pure capacity equipment, especially from foundries or subcontractors, have approached zero recently." One ray of hope for recovery is in the development of next-generation production equipment that can handle 300-mm wafers, silicon-on-insulator (SOI) ICs, copper (Cu) metallization, and other advanced semiconductor techniques being developed. Cascade Microtech's recently announced S300 RF/Microwave Probe Station for 300-mm on-wafer test is an example of this production equipment **(Fig. 1)**.

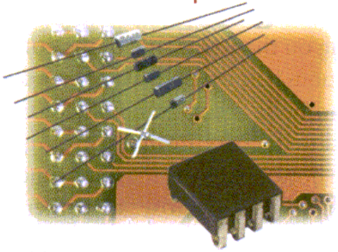
Not surprisingly, most managers in T&M companies believe that the turnaround in the communications industry hinges on the development of new products. And that effort must begin at home. Dave Myers, Vice President of the Component Manufacturing Market Solutions Unit of Agilent Technologies (Palo Alto, CA), states that his company is "focusing more of our development effort on R&D tools. One of the tried and true strategies for ourselves and our customers is new products." Myers is another executive who attributes the deepest segment of the downturn to manufacturing. He says, "Our data shows that customers are investing more in R&D than last year. New products are important in remaining healthy in the downturn and coming out in good shape at the other end. We are committed to

Continued on page 38



2. The Tektronix NetTek base-station field tool is a productivity-enhancing test instrument that allows technicians to quickly and reliably verify base-station functionality.





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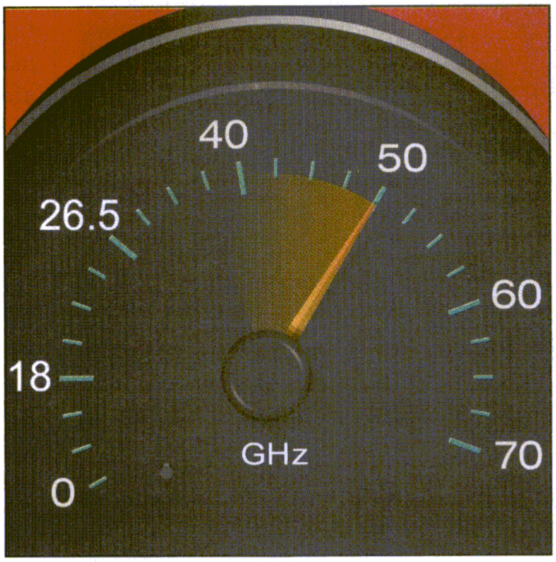

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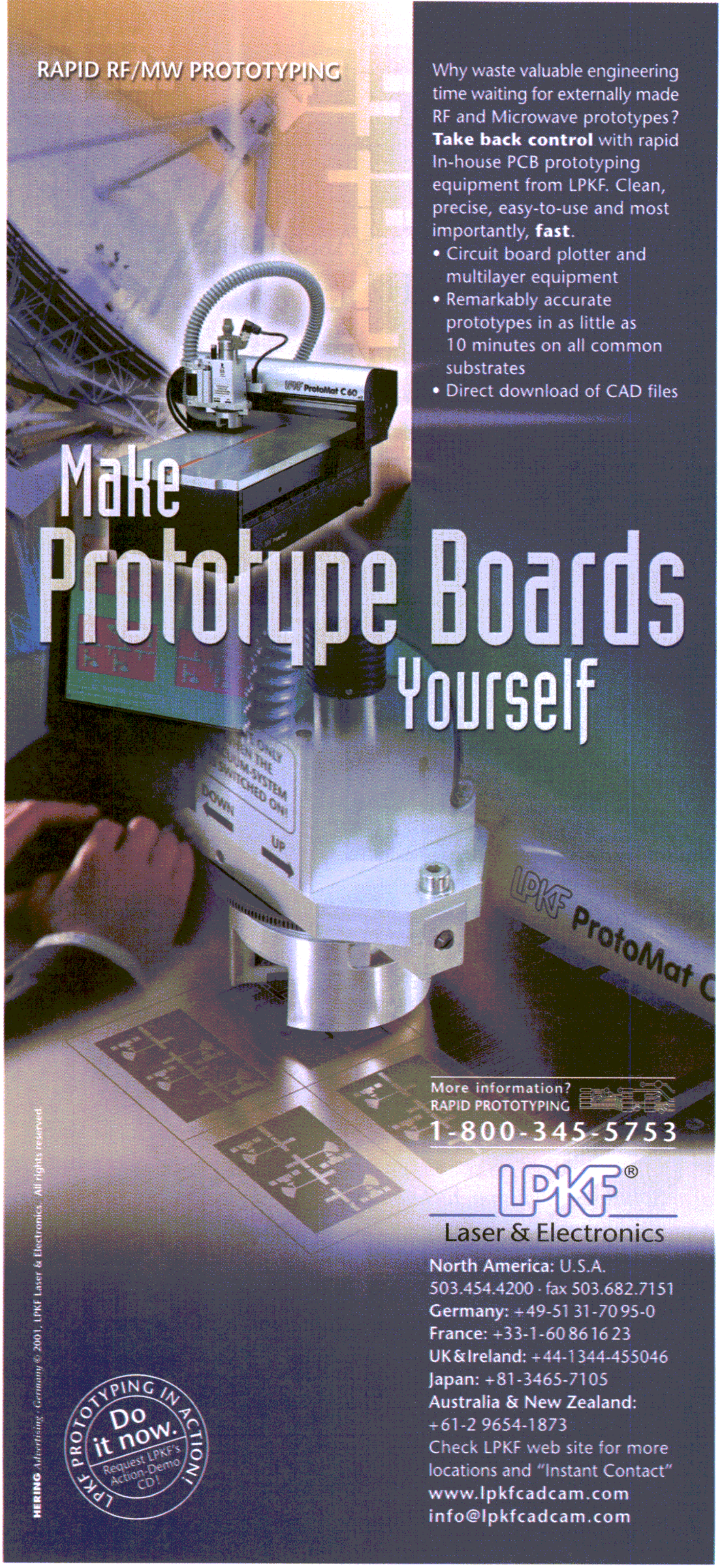

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getting out more new products in the next year than in the last 12 months, and even more in the 12 months after that." Although Agilent's focus has shifted to committing more resources to R&D, it is not a wholesale change in the company's strategy.

A similar view is expressed by Brian Reich, Worldwide Business Development Manager of the Optical and Mobile Business Units of Tektronix (Beaverton, OR). Similar to the communications industry as a whole, Tektronix has been affected by the weak business climate, but Reich claims, "Our overall strategy hasn't changed a bit. We're focusing on the zone of communications and computers and the convergence of these two technologies." From a product standpoint, Tektronix will put its resources into two catagories of test equipment: those for infrastructure installation and monitoring applications, and instruments for design and production testing. In the mobile-communications market, the emphasis is shifting from voice to data. At the same time, network operators are putting less focus on obtaining the highest technology available and more on being profitable. Quality of service (QoS) and cost reduction are high-priority items in this strategy.

One way to lower costs is by using test equipment that is simple for a service provider's technicians to use. Reich says, "It must be cost-effective, not require a lot of training time, not be overloaded with functionality, yet have a sufficient feature package at an affordable price." One of these tools is the company's NetTek™ base-station field tool aimed at allowing maintenance technicians to quickly and reliably verify a base station's functionality under any weather conditions in the field **(Fig. 2)**. The instrument is modular, consisting of a multistandard measurement module housed in a NetTek installation-and-maintenance mainframe. Standards that can be handled are the Global System for Mobile Communications (GSM), IS-136 (time-division multiple access

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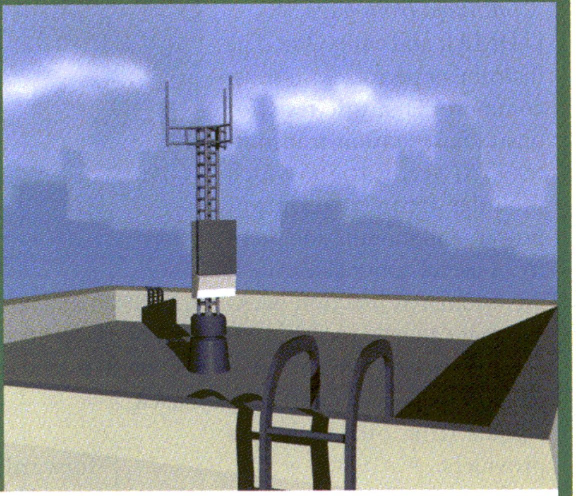

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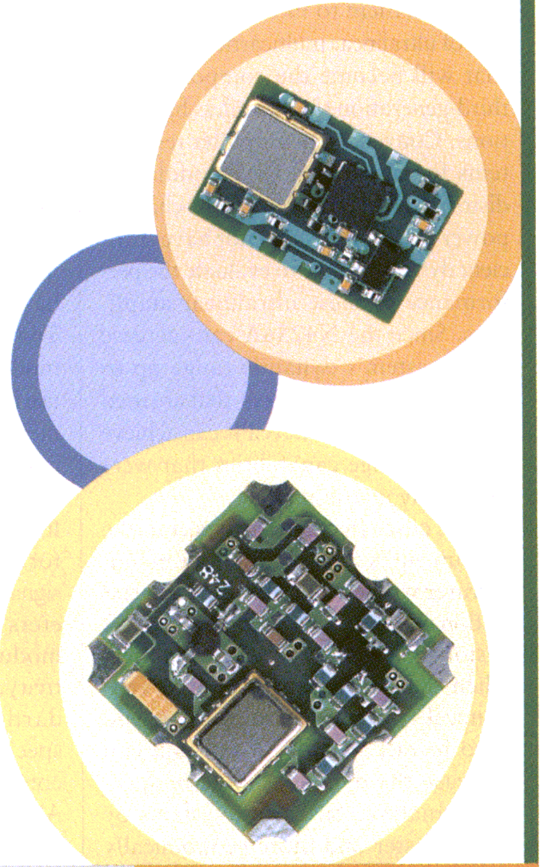

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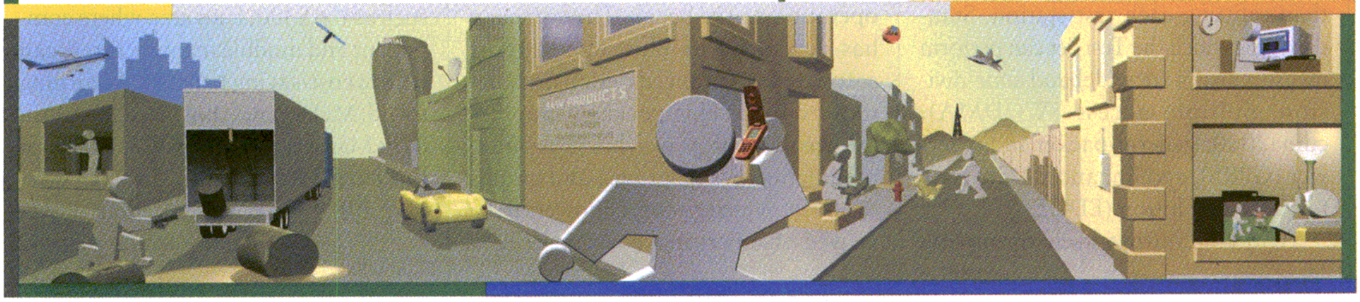

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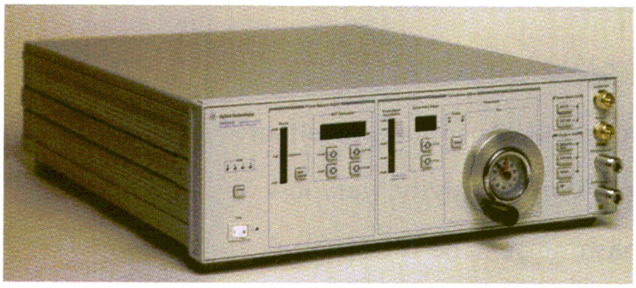
Continued from page 38

[TDMA]) and cdmaOne. The instrument performs the most common diagnostic tests for onsite base-station transmitter (Tx) verification, which includes frequency, output power, and modulation quality. A useful optional feature is an automated function package that can help locate interference sources such as TVs, pager signals, and interfering signals from other wireless providers.



3. Multicarrier amplifier manufacturers can improve the capability of production-test stations with Agilent's N4256A test set, which extends dynamic-range measurement performance.

Cost-effectiveness is a key selling point of Agilent Technologies' new N4256A Amplifier Distortion Test Set **(Fig. 3)**. The instrument is designed to boost the range of existing test systems to enable them to measure the distortion of ultralinear multicarrier amplifiers that will become the components of third-generation (3G) wireless base stations. Conventional amplifier test systems for measuring intermodulation distortion (IMD) and adjacent-channel power ratio (ACPR) do not have sufficient dynamic range to evaluate the performance of these ultralinear amplifiers. Since the N4256A can increase a test system's dynamic range up to 25 dB, spectrum analyzers that are used to measure IMD and ACPR can achieve dynamic-range capabilities that were previously unattainable.

The cost-effectiveness aspect of the instrument is that an amplifier manufacturer would need to equip each test station with new test equipment to meet customer demands for 3G amplifiers when that situation arises. The economical solution, according to Agilent, is to install an N4256A which can increase the dynamic range of spectrum-analyzer-based test systems by 25 dB faster and more economically than refitting each test station. Standards for which the Test Set can perform measurements are wideband code-division multiple access (WCDMA), cdma2000, general-packet radio service (GPRS), and Enhanced Data Rate for GSM Evolution (EDGE).

Also committing itself to moving forward with new product development is Anritsu Co. (Richardson, TX). Scott Sullivan, Assistant General Manager of the Advanced Technology Division, says, "We are under a great deal of pressure from customers to release new products even more quickly so that they can bring their products—generally user terminals/handsets—to market more quickly."

One wireless technology that could get the hi-tech ball rolling is long-on-promise, short-on-product Bluetooth. To aid Bluetooth component makers to move products out the door, Anritsu has designed its MT8850A Bluetooth Test Set for production test of chip sets, modules, and consumer products that use Bluetooth radios **(Fig. 4)**. The instrument meets industry requirements for conducting measurements in accordance with RF Test Specification V0.09. It also uses the Bluetooth protocol stack for full implementation of test-mode signaling. The test set can analyze parameters such as RF power, frequency, modulation, and receiver (Rx) sensitivity. In addition to conducting standard measurements to Bluetooth specifications, the MT8850A can be configured to run custom test scripts. All measurements to be made can be preprogrammed in to enable single-keystroke operation on the bench. The company has developed its BlueSuite support software for advanced design on Bluetooth radios. This package supports the creation of power-burst profiles, modulation eye diagrams, and graphs of all 79 frequency-output powers to be viewed on a personal computer (PC).

What will it take to get the industry out of the doldrums?

The attitudes that best characterize T&M manufacturers during the current communications industry slump are confidence in the future and the need to continually invent new products. For LeCroy, Mike Lauterbach says, "We're not slowing any plans for technology development or new product introductions next year. We plan to introduce one major new product each quarter."

Eric Strid of Cascade Microtech believes that "successfully navigating a downturn requires that you have continued to develop the technology and products to address evolving customer needs. Any vendor who has slowed down will be out of the game. More than anything else, new technology will pull us out of this downturn as it has in previous cycles." His company's S300 Probe Station (Fig. 1) can handle wafer sizes up to 12 in. (300 mm). The station performs a variety of semiconductor-measurement functions: device characterization, wafer-level reliability, electronic testing, device modeling, and yield enhancement. Supporting the station is a new software package known as Nucleus 2.1 Prober Control Software. This program monitors and analyzes RF or microwave data in real time through a graphical user interface (GUI) composed of a wafer map and histogram statistics. A multiuser log-in feature enables more than one person to operate the software, while maintaining lab security. Another feature of the software is its ability to provide a user with graphical subsite control through an editor that maximizes test accuracy.

Automatic test equipment (ATE), such as the S300, is an area where component and module manufacturers can realize cost-saving benefits. According to Ed McDonald, Business Development Manager for ATE systems integrator In-Phase Technologies, Inc. (Clarksburg, NJ), "The communications down-

Continued on page 42


The one constant
Change
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Continued from page 40

turn has not had as great an effect on ATE manufacturers as it has on box manufacturers, especially in fiber optics. Fiber-optics test boxes cost so much—$200,000 to $250,000—that it is difficult for companies to justify such a large capital equipment outlay in the face of a downturn." McDonald believes that test equipment will be increasingly outsourced, similar to how manufacturing and design engineering are being contracted out to companies with expertise in a specific discipline [Note: The electronics manufacturing services (EMS) industry, which is the new name for outsourcing, is a $90 billion industry which is forecast to grow to several hundred billion in the next few years. Not only is manufacturing being outsourced, but product design, prototyping, first-build, and test are also on the move from traditional manufacturers to smaller companies that specialize in design-engineering services and then provide the interface between OEMs and EMS companies that do the build.]

One of the reasons why manufacturers will come to rely more on outsourcing their ATE requirements is the reduction in personnel brought about by the economic problems of the industry. "When times were better," says McDonald, "many engineers were building test equipment instead of working in the core competencies of the company." With staff reductions, there are fewer in-house test engineers to build equipment to test a product. Therefore, they must pull in design engineers to assist with this task, but this takes the designers away from their primary function of developing new products. Not only that, but there are many hidden costs associated with keeping the test-equipment operation in house.

Outsourcing to an ATE systems inte-

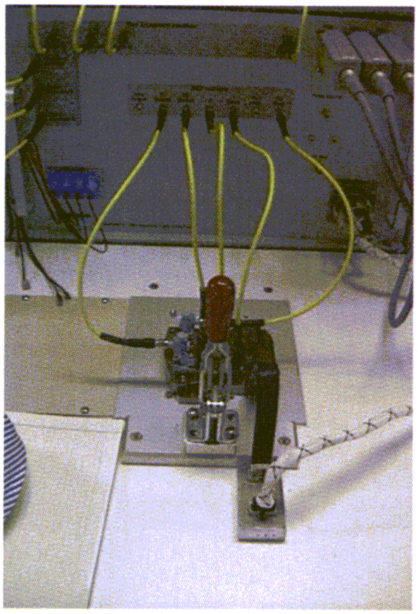
Continued on page 44

4. Anritsu's MT8850A Bluetooth tester can run Bluetooth test routines or can be configured to run custom tests on a range of system parameters.

Continued from page 42

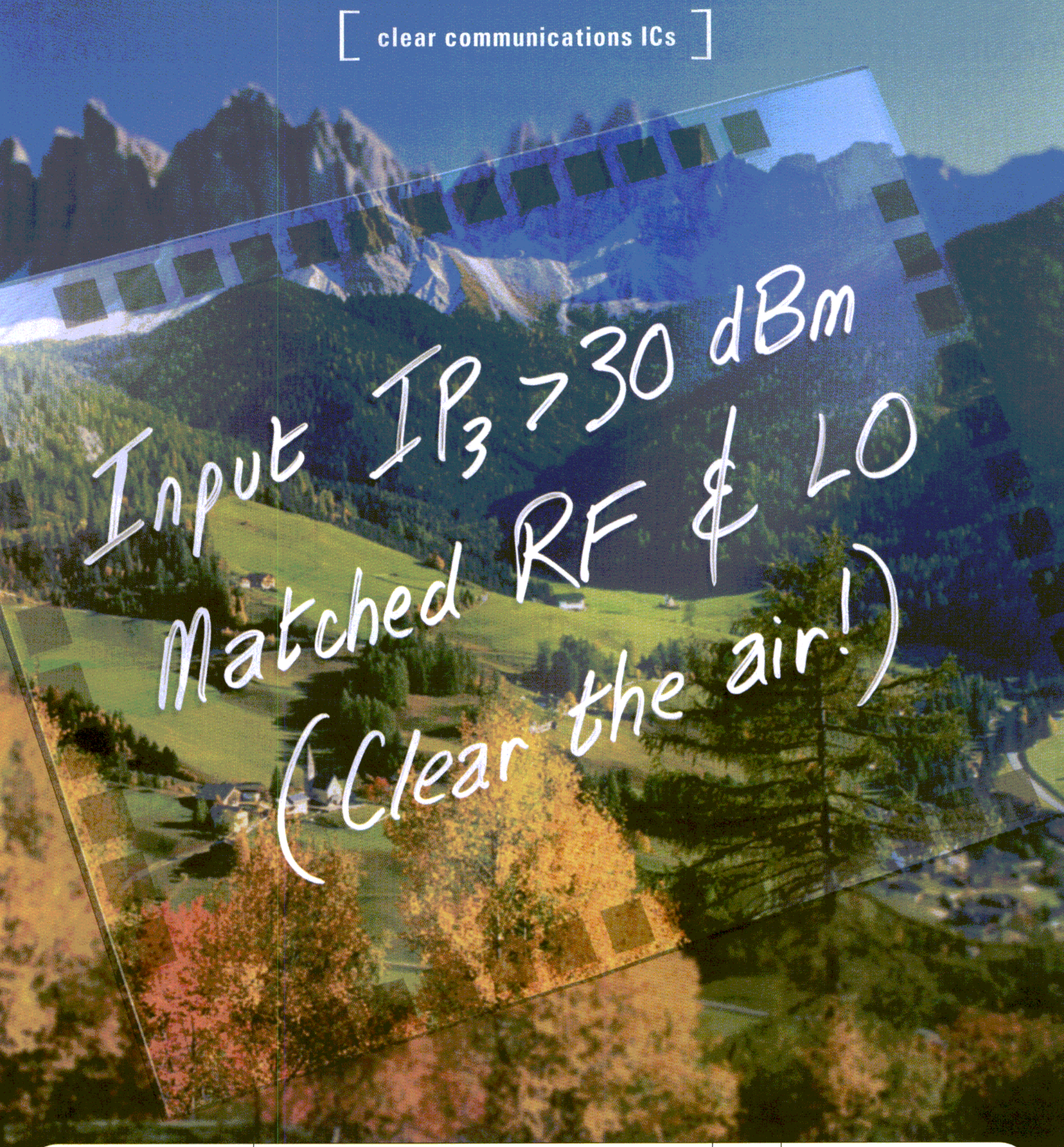
grator may make economic sense since the company will know at the outset exactly what the equipment will cost. Moreover, there is a much better chance of getting it on time than if manufactured in-house. This is because few companies have the expertise to manage such a project from the hardware side, to say nothing of the software, which is the most complex part of a system.

In-Phase recently introduced a local-multipoint-distribution-service (LMDS) automated test system to address the production-test requirements of transceiver-related components found in a typical LMDS. The system is comprised of a combination of commercially-available-off-the-shelf (COTS) test equipment and a number of interface and control modules designed to meet certain component specifications. The test fixture shown in **Fig. 5** can perform measurements up to 40 GHz and incorporates rapid install-and-remove features that minimize handling times associated with typical production-testing routines.



5. This test fixture is the measurement apparatus of In-Phase Technologies' 40-GHz automatic-test-equipment station that is for LMDS and other microwave applications.

While the communications industry currently appears to be in free fall, all of those interviewed for this article express confidence that a full recovery will take place, but no one knows when. That is understandable, since most observers agree that this technological downturn has been sharper and deeper than any in recent memory. The recovery—when it occurs—could be just as sharp, but some of the much-ballyhooed technology of the past two years may take longer than expected to return to earlier predicted growth paths. Technologies such as 3G wireless and Bluetooth will eventually reach their forecasted goals, but the arrivals will likely be slowed by the damage incurred in this downturn. **MRF**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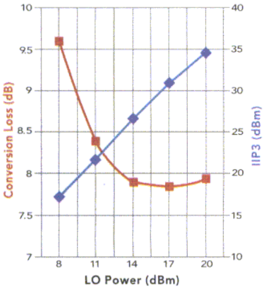
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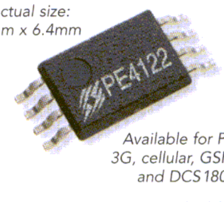
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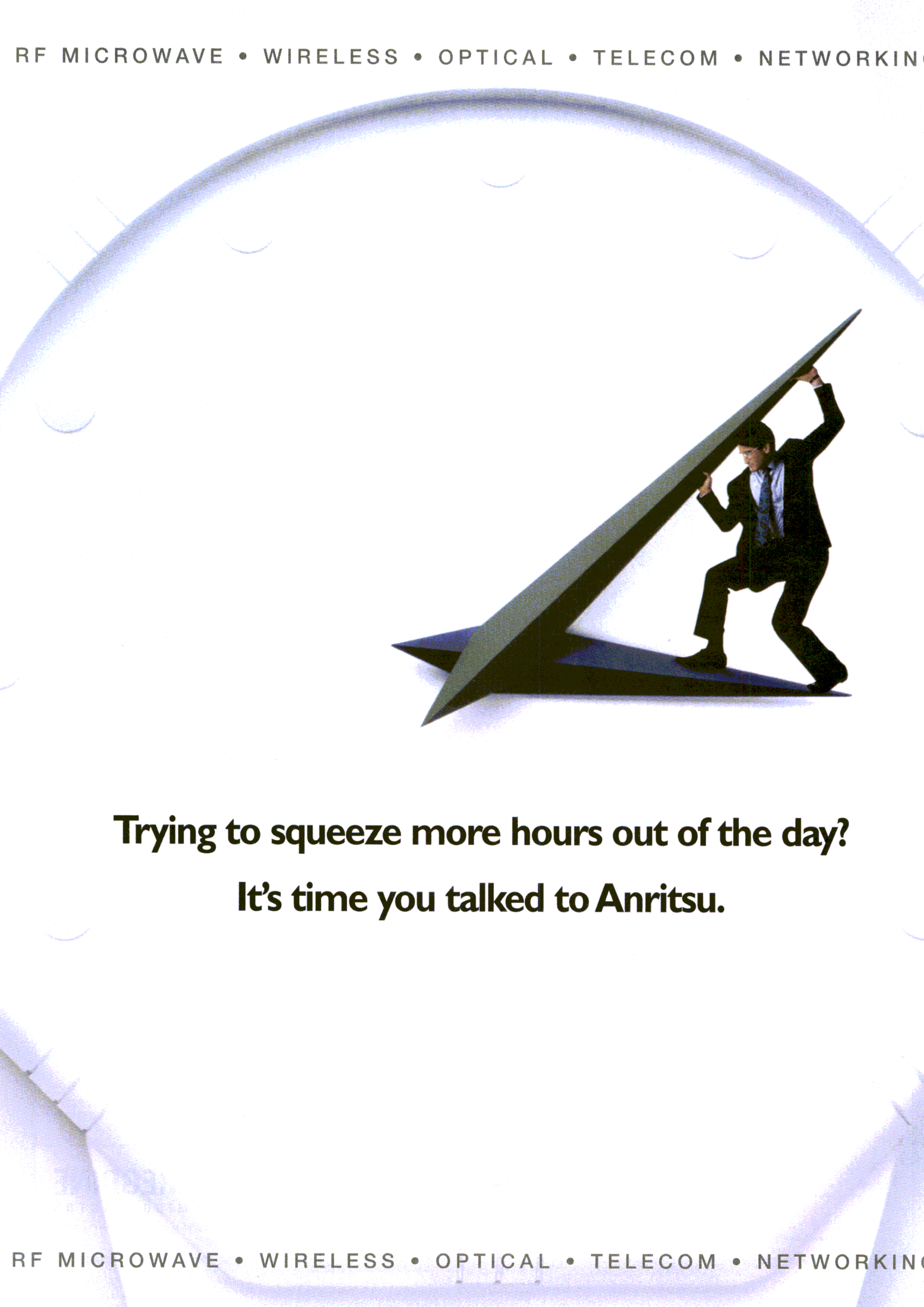
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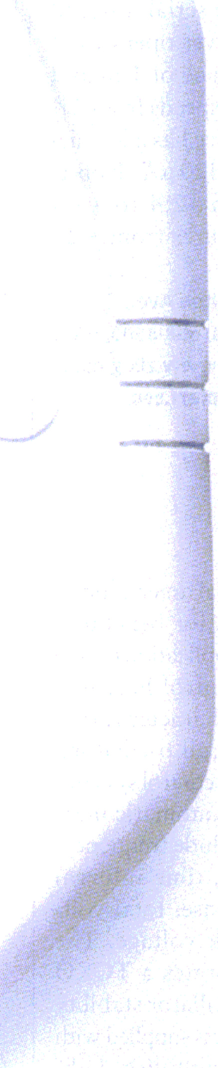

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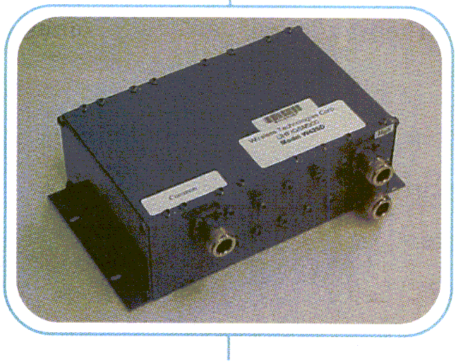

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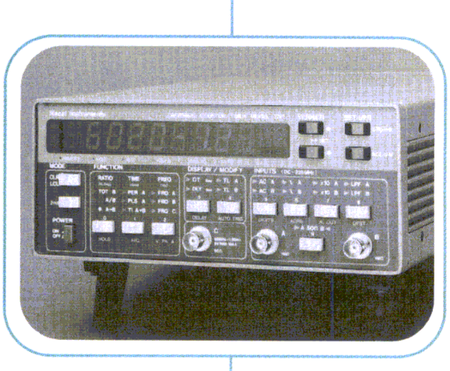

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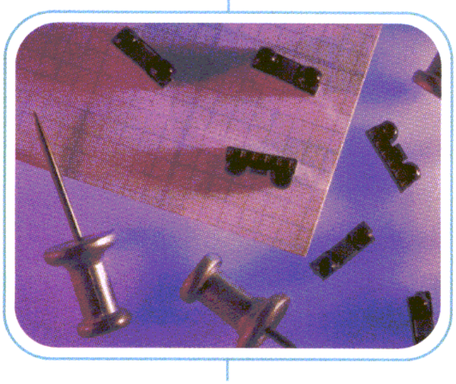

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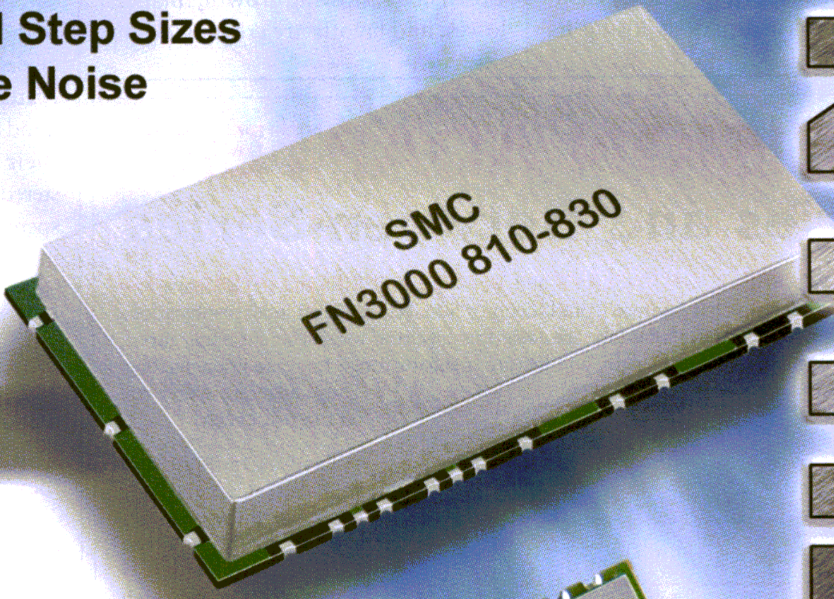
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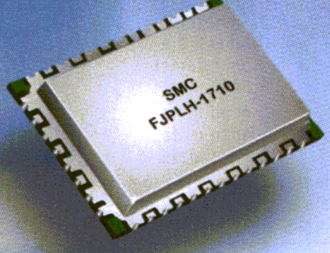
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Is The Hi-Tech Boom Over?

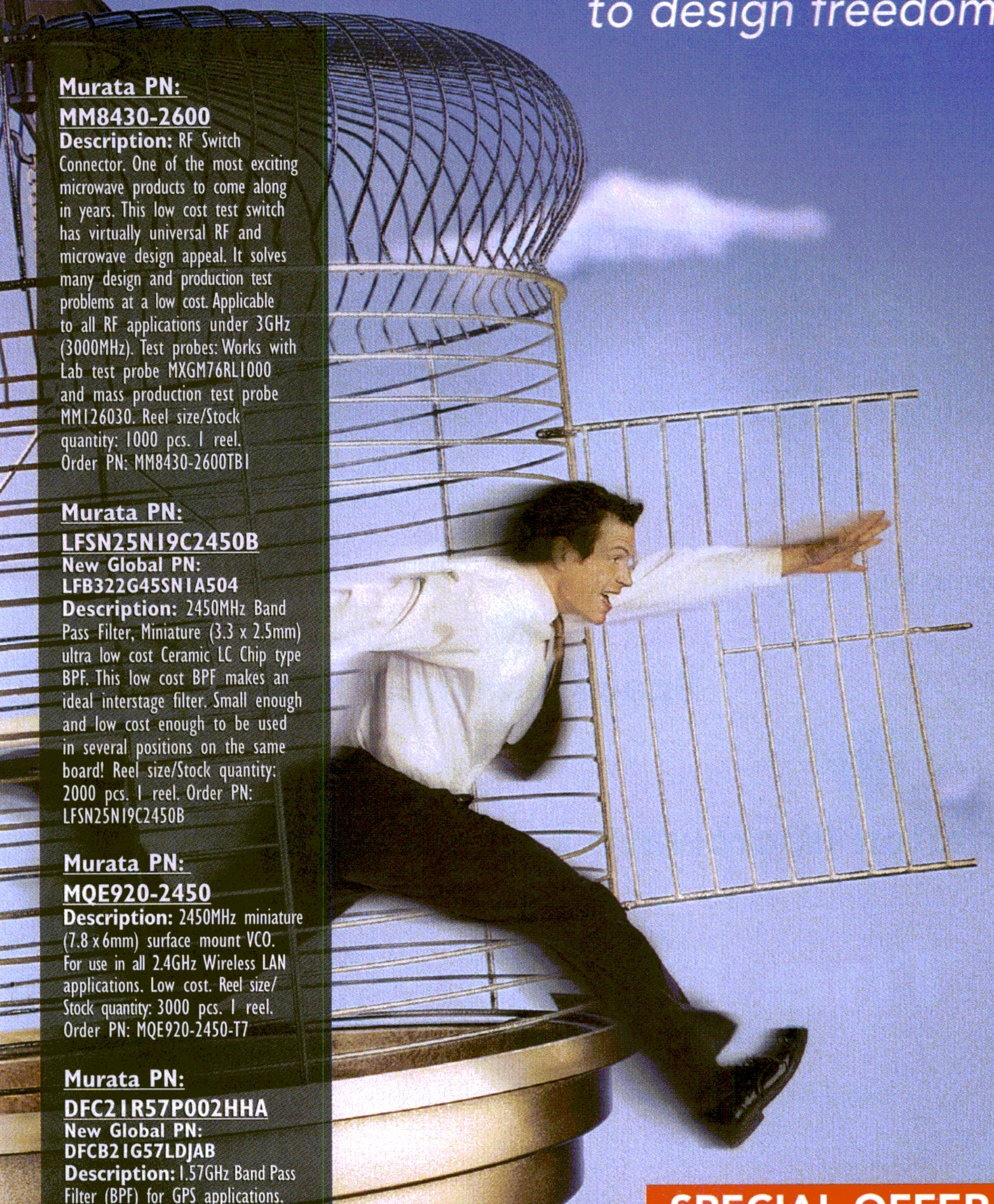
BATTERED BY A stumbling economy and a roller-coaster stock market, the high technology that has ignited the US economy for the past decade is losing its luster in the eyes of some economists and analysts. According to a recent story in *USA Today*, slowing growth, financial losses, and layoffs are creating doubts that hi-tech will ever return to the "breakneck growth of the past decade."

Some nay-sayers believe that a return to the fast-paced growth of hi-tech is not close at hand since much of it was generated by overspending on technology goods by businesses afraid to fall behind their competitors. This view is bolstered by certain unsettling statistics: tech spending fell at a 6.4-percent annual rate in the first quarter—the first decline since 1991; the Nasdaq has fallen 55 percent from its peak last March, taking with it many of the Internet dot.coms and infrastructure suppliers; and PC manufacturers are struggling since more than half of US homes have a PC and they now have become a commodity.

On the other side are those who see the current slowdown as a normal blip common to many evolving industries. Moreover, American ingenuity has created an amazing array of new technology over the past half century: transistors in the 50s, ICs in the 60s, PCs in the 70s, the Internet in the 80s, and wireless communications in the 1990s. In fact, wireless could be the technology that leads to the next economic boom. For example, in the US, only 5 percent of the nation's 100 million wireless phone owners use them for e-mail or web browsing. And the build out of the wireless infrastructure (worldwide) is in its early stages.

Another sleeping giant is high-speed fixed broadband for Internet access, video on demand, e-commerce, and virtually all of an individual's communications needs. Further out is the prospect of nano technology, manufacturing on a molecular scale. It may be possible one day to make a computer chip out of atoms, resulting in computers with amazing power.

The recent ills of high technology are normal in the evolution of any high-risk business or industry. Those who believe that the boom is over should think about what, if anything, can replace high technology as the engine of growth in the 21st century. MRF



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CONTRACTS

BAE SYSTEMS—Has received a contract for more than $30 million from Raytheon Systems to deliver five Defensive Aids Group (DAG) integrated systems for the United Kingdom's Ministry of Defense Airborne Stand-Off Radar (ASTOR) program. The systems will be installed aboard the Royal Air Force's "Global Express" aircraft. These are commercial business jets, which will be modified to carry the radar, air-to-ground data links, and defensive aids equipment for the ASTOR system.

Motorola—Has won a $213 million supply contract from Hunan Branch of China Mobile Communications Corp. (Hunan Mobile) for the expansion of the operator's GSM-900/1800 dual-band network in Hunan Province. Under the contract, network expansion is scheduled in two phases. Phase one, totaling $154 million, began in April and is targeted for completion by year's end. Phase two, totaling $59 million, will then begin with completion scheduled for the first half of 2002. The expansion projects are expected to increase the network capacity by 2.8 million subscribers.

Channel Master, LLC—Was selected by WildBlue Communications Ltd. to build the satellite mini-dish antennas that consumers will use to access WildBlue's two-way wireless broadband service. These mini dishes can also receive the DBS signals for digital satellite TV.

Tektronix, Inc.—Announced that Dialog, a fixed-telephony operator based in Wroclaw, Poland, has placed an order for Tektronix' telecommunications network-monitoring system.

Endwave Corp.—Has received a multimillion-dollar initial order from DMC Stratex Networks, a solution provider for cellular applications and broadband wireless access. The order requires Endwave to design, manufacture, and deliver custom millimeter-wave transceivers.

Alcatel—Announced that CP Orange, a partnership with Orange SA and CP Group, has awarded Alcatel a $32 million turnkey contract for delivery of a new nationwide GSM-1800 network in Thailand. It will be the biggest GPRS network in the Asia Pacific and the first of its kind in Thailand.

FRESH STARTS

USCarrier Telecom, LLC—Has received a commitment of $25 million in long-term financing. The proceeds from the debt and equity funding will be used for continued growth and expansion of high-speed telecommunications services in the Atlanta region and major/emerging markets throughout Georgia and the Southeast.

3DSP Corp.—Has moved its headquarters to a 20,000-sq.-ft. facility in the Irvine Spectrum area at 16721 Laguna Canyon Rd., Irvine, CA 92618. Their new phone number is (949) 435-0600 and their new fax number is (949) 435-0700.

PanaVise—Has named The McKim Group to represent the full line of PanaVise products in Europe, South America, Africa, Australia, and Asia. McKim will assist PanaVise by maintaining contact with foreign importers, combining orders to reduce shipping charges, and providing quick response to requests for proforma invoices and technical information.

Semflex—Has appointed two new sales representatives to handle their cable-assembly product lines. Tritek N.W. will represent the company in the Northwest from offices in Washington and Oregon, and Spectrum Sales, Inc. was appointed for metro New York, New Jersey, along with Connecticut's Fairfield County.

Accelerated Technology, Inc.—Has announced Nucleus support for the IQ2000T family of network processors from Vitesse Semiconductor. This new partnership offers users yet another option for developing networking and communications applications with ATI's Nucleus PLUS real-time kernel.

Stanford Microdevices (SMDI)—Announced a foundry agreement with RF Micro Devices where SMDI's RF ICs will be manufactured in RF Micro Devices' 4-in. (10.16-cm) GaAs HBT fabrication facility, located in Greensboro, NC.

Labtech—Has opened a MMIC assembly facility at its headquarters in Presteigne, Wales. Labtech has invested 200,000 pounds ($280,000) commissioning the facility and recruited and trained additional members of staff in the specialist assembly techniques required. The 500-sq.-ft. facility is equipped with semi-automatic wedge bonders and manual die bonders for attaching microwave die to Labtech's specialist metal-backed polytetrafluoroethylene circuits. The facility will be used to assemble single-chip and multichip modules for radio links used in cellular-phone networks and LMDS systems.

Gowanda Electronics—Has unveiled its new website at www.gowanda.com. The website contains product, technical, and company information in a user-friendly format. For those familiar with Gowanda's inductors, products can be searched by part number. For those organizations new to the company, products can be searched by properties—by specifying desired inductance values and/or current ranges.

Applied Wave Research, Inc. (AWR)—Has entered into a long-term strategic alliance with P&H Technology Consultants to integrate simulation with test to provide a complete verification suite. SoftPlot for Microwave Office provides direct access to popular test equipment for manufacturers such as Anritsu Wiltron, Rohde & Schwarz, Marconi Instruments, Fluke/Philips, Tektronix, Boonton, Lecroy, Yokogawa, IFR, Wandel & Goltermann, Advantest, Hewlett-Packard Co., and Agilent Technologies.

Spectrum Signal Processing, Inc.—Formed a marketing and technology alliance with Broadcom Corp. to pursue research, development, marketing, and sales initiatives in the fast-growing VoP market, which encompasses VoIP and Voice over ATM (VoATM). MRF

Conlon Named COO Of Palomar Technologies

KEVIN CONLON has been promoted to the position of COO at Palomar Technologies, Inc. of Vista, CA. Mr. Conlon first joined Palomar Technologies in December 1997 as vice president of sales and marketing.

NTRU—ELIZABETH ROBERTSON to vice president of finance and CFO; formerly CFO at Authentica.

Green Hills Software, Inc.—PETER H. FOLEY to CFO; formerly CFO and COO at CyberXpo.

Artesyn Communication Products, LLC—JOE LUGO to vice president of engineering; formerly director of advanced product development at the Eaton Corp. Innovation Center.

JBRO Batteries—KURT PADERA to vice president of sales and marketing for the OEM division; formerly engineering manager at TDI Batteries, Inc.

fiberspace, Inc.—PATRICIA WEHR to the position of vice president of finance and administration; formerly CFO at Haskel International, Inc. Also, ALAN WILMER, PH.D. to the Technical Advisory Board; remains as professor of electrical engineering at the University of Southern California.

Excellon Automation Co.—BOB BELL to general manager of the Mechanical Business Unit; formerly general manager of Custom Engineering. Also, GEORGE SCHMELTZER to the position of general manager of the Customer Engineering Business Unit; formerly director of Information Technology.

The Cellular Telecommunications & Internet Association (CTIA)—AMY MCKENNIS to Senate director for government affairs; formerly legislative assistant to Senator Fred Thompson.

I-Bus/Phoenix—JACK DAVIS to the position of global marketing director; formerly director of sales and marketing at Macrolink.

TOUCHAMERICA—JOE CASTON to director of marketing and strategic development; formerly general manager for New Edge Networks.

Antenna Specialists—THOMAS L. HOLMAN to quality assurance manager; formerly quality assurance manager for Hy-Level Industries.

Allgon AB—JEFF BORK to president and CEO; formerly president of Dynal Biotech.

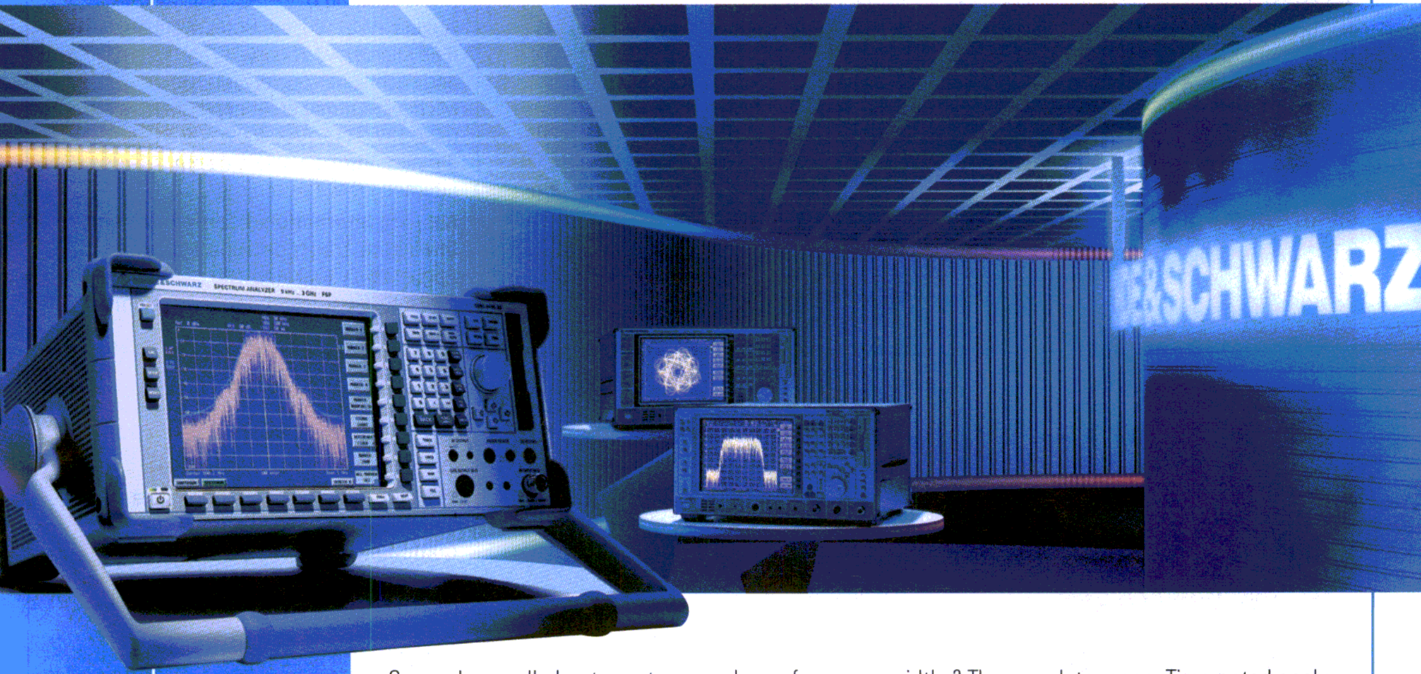
STMicroelectronics—MICHAEL MARKOWITZ to director of media relations; formerly held the title of vice president of content and community at Innovation Chain.

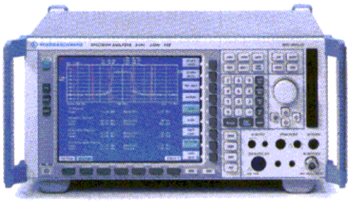
Insilco Technologies—COLIN ANDERSON to European business-development manager; formerly program manager for major telecommunications accounts at LEONI.

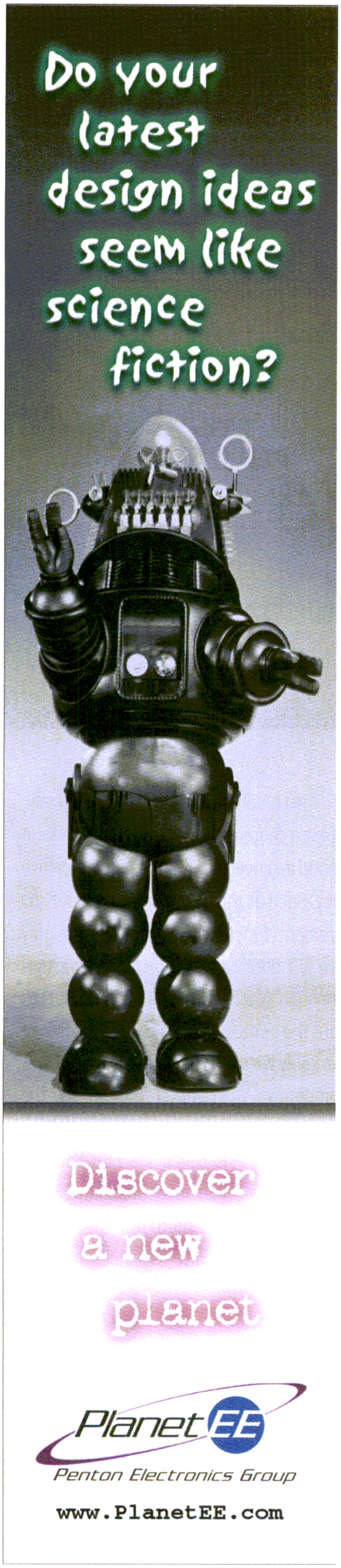
Western Multiplex Corp.—BERNARD PICOT to vice president of sales for Latin America, the Caribbean, and Europe, Middle East, and Africa (EMEA); formerly director of international sales for EMEA and Latin America at Proxim, Inc.

ITT Industries, Avionics Division—JEFF GERNITIS to vice president and director of engineering; formerly director of project engineering.

Rohde & Schwarz—DR. WOLFGANG WINTER to managing director for sales in Latin America; formerly director of sales in Western Europe. MRF


&SCHWARZ





SHORT COURSES

Electrical Grounding of Communications Systems
August 1-3 (Madison,WI)
Dept. of Engineering Professional Development
University of Wisconsin-Madison
Madison, WI 53706
Amy Lensing
(800) 462-0876, FAX: (608) 263-3160
e-mail: custserv@epdweb.engr.wisc.edu
Internet: www.epdweb.engr.wisc/edu

Interference Analysis and Suppression Techniques for Wireless Communications
August 6-10 (Berkeley, CA)
Continuing Education in Engineering,
the College of Engineering
University of California, Berkeley
Berkeley, CA 94720-7010
(510) 642-4151, FAX: (510) 642-6027
e-mail: course@unx.berkeley.edu

Digital Signal Processing: Theory, Algorithms, and Implementation
August 13-17 (Los Angeles, CA)
UCLA Extension, Dept. of
Engineering, Information Systems
and Technical Management
Los Angeles, CA 90024-2883
(310) 825-1047, FAX: (310) 206-2815
e-mail: mhenness@unex.ucla.edu
Internet: www.uclaextension.org/short-courses

EMC Testing and Measurements
August 17 (Gaithersburg, MD)
Washington Laboratories Ltd.
7560 Lindbergh Dr.
Gaithersburg, MD 20879
(800) 839-1649, FAX: (301) 417-9069
e-mail: info@wll.com
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EMI Control Courses: Grounding and Shielding, System EMC Design and Installation, and Diagnostics & EMI Fixes
August 21-24 (Virginia Beach, VA)
Don White Consultants, Inc.
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Warrenton, VA 20187
(540) 351-0088, FAX: (540) 347-5813
e-mail: emc-donwhite@crosslink.net

Introductory RF and Microwaves
September 20-21 (Lake George, NY)
R.A. Wood Associates
1001 Broad St., Suite 450
Utica, NY 13501
(800) 966-3606, FAX: (315) 735-4217
e-mail: RAWood@rawood.com
Internet: www.rawood.com

IEEE Topical Workshop on Power Amplifiers for Wireless Communications
September 10-11 (San Diego, CA)
IEEE Microwave Theory and Techniques
Society (MTT-S) in collaboration with the
UCSD Center for Wireless Communications
University of California-San Diego
Michell Parks
(858) 534-2498
e-mail: parks@ece.ucsd.edu

MEETINGS

2001 IEEE Radio and Wireless Conference (RAWCON2001)
August 19-22 (Boston Hotel, Waltham, MA)
IEEE Microwave Theory
and Techniques Society (MTT-S)
Michael Heutmaker, General Chair
(609) 639-3116, FAX: (609) 639-3197
e-mail: heutmaker@lucent.com
Internet: www.rawcon.org.

IEEE 4th International Conference on Intelligent Transportation Systems
August 25-29 (Oakland, CA)
IEEE Intelligent Transportation Systems Council
Dept. of Electrical Engineering
University of Washington
P.O. Box 352500
Seattle, WA 98195-2500
Internet: www.ieee.org/itsc/2001

2001 IEEE Emerging Technologies Symposium on Broadband Communications for the Internet Era
September 10-11 (Dallas, TX)
IEEE Dallas Section
Jon Veihl
IEEE ETS
P.O. Box 852492
Richardson, TX 75085-2492
(972) 952-0011, FAX: (972) 952-0054

Silicon Monolithic Integrated Circuits in RF Systems
September 12-14 (Ann Arbor, MI)
IEEE MTT-S, NASA Glenn Research Center,
the National Science Foundation and the
Army Research Office
Center for Professional Development
University of Michigan,
College of Engineering
Beth Hillis, Program Coordinator
(734) 647-7200, FAX: (734) 647-7182

34th International Symposium on Microelectronics (IMAPS 2001)
October 9-11 (Baltimore Convention Center, Baltimore, MD)
IMAPS
611 2nd St. NE
Washington, DC 20002
(202) 548-4001, FAX: (202) 548-6115
e-mail: IMAPS@imaps.org
Internet: www.imaps.org

2001 IEEE GaAs IC Symposium
October 21-24 (Renaissance Harborplace Hotel, Baltimore, MD)
IEEE MTT-S, Electron Devices Society, and
Solid State Circuits Society
2001 IEEE GaAs IC Symposium
Piscataway, NJ 08855
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(732) 562-5350, FAX: (732) 981-1203
e-mail: m.e.clemente@ieee.org.

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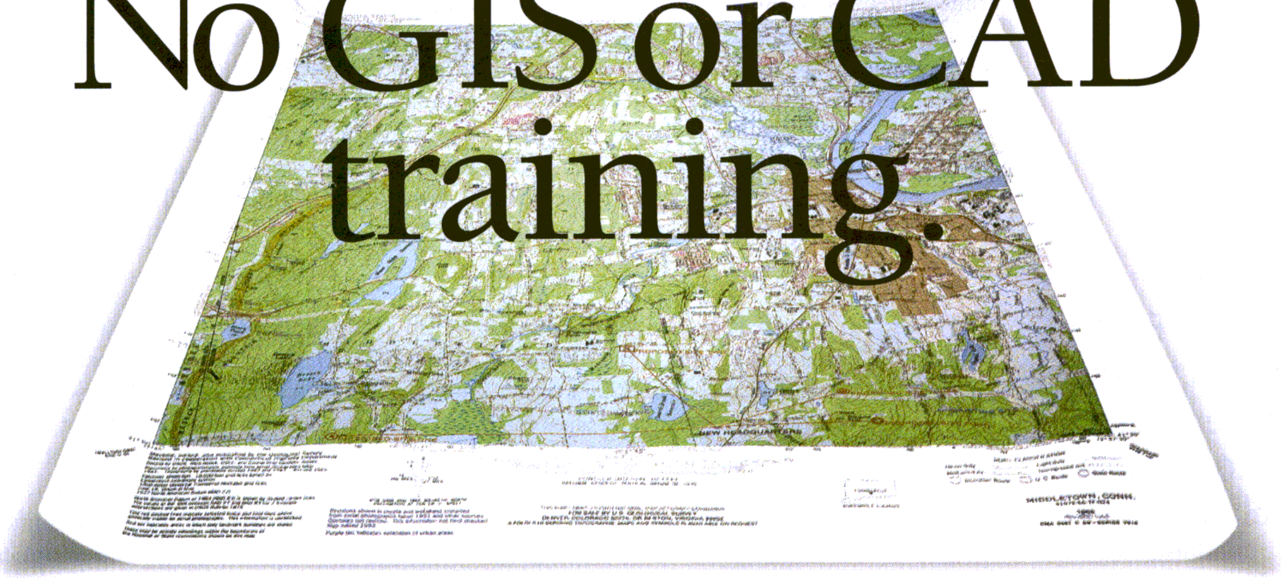

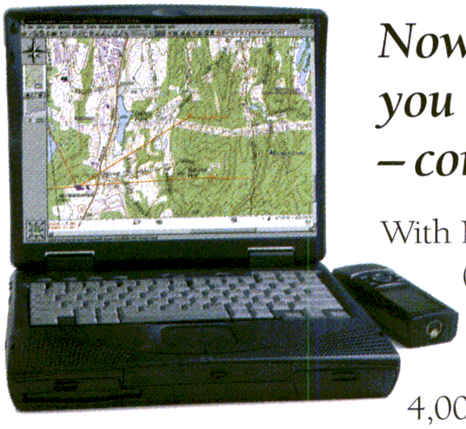

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Researchers mate solar cells with antennas to save space on satellites

COMMUNICATIONS SATELLITES NORMALLY use separate solar cells and antennas. These two components compete with each other for the scarce surface area available on the satellite. Solar cells form a large part of communications satellites, providing large, flat surfaces over which antennas can be mounted or printed. If they could somehow be combined into one element, it would save valuable real estate. Printed antennas, commonly used in microwave communications, are naturally suited for this combination, especially if their radiating patches can be isolated from their feed circuits. S. Vaccaro, J.R. Mosig, A.K. Skrivervik, and J.F. Zurcher of the Ecole Polytechnique Federale (EPFL) in Lausanne, Switzerland, P. Torres and A. Shah of the University of Neuchatel in Neuchatel, Switzerland, and P. de Maagt and L. Gerlach of the European Space Agency in Noordwijk, The Netherlands have introduced such a hybrid device—a solar antenna, or solant. The device uses uses a patch antenna printed in a multilayer substrate and incorporates solar cells as additional thin layers. The combination is made possible through the use of two breakthroughs: the use of amorphous-silicon, thin-film solar cells, and their inclusion in the EM design to achieve a compact, optimized structure. The 2 × 4 array operates at 3.76 GHz and supplies +5 VDC at 100 mA. See "Combination of Antennas and Solar Cells for Satellite Communications," *Microwave and Optical Technology Letters,* April 5, 2001, Vol. 29, No. 1, pp. 11-17.

GaAs MESFET model predicts large-signal, optoelectronic behavior

IT IS WELL-known that, when a GaAs MESFET is illuminated by a laser at a fixed wavelength, absorption effects take place at the gate-drain and gate-source interelectrode spaces, and free-carrier photoexcitation is induced in the active-area level of the device. Thus, this type of FET can be embedded on a monolithic chip as a photodetector to act as an optical port in optoelectronic circuits. With the growing interest in the large bandwidth that these devices can handle, much research has been devoted to characterizing them and modeling their behavior under optoelectonic conditions. A complete nonlinear-device model must take the effects optical illumination on the bias-dependent dynamic behavior that effects the output power and efficiency of these devices into account. A study undertaken by J.M. Zamanillo, C. Navarro, C Perez-Vega, A. Mdiavilla, and A. Tazon of the University of Cantabria, Santander, Spain modeled the optical large-signal behavior of this device and contributes to the knowledge of the optical laws responsible for the most dependent parameters, including the nonlinear capacitances C_{gs} and C_{ds}. The researchers used an 830-nm laser diode pigtailed to a single-mode optical fiber to illuminate a GaAs MESFET at optical power levels ranging from 0.01 to 10 mW. The test setup also included a pulsing system coupled to the drain and source and their DC power supply through bias tees. A standard PC controlled the optical incident power, the pulsing system, and a network analyzer. See "Large-Signal Model Predicts Dynamic Behavior of GaAs MESFET Model Under Optical Illumination," *Microwave and Optical Technology Letters,* April 5, 2001, Vol. 29, No. 1, pp. 25-31.

Resistive sheets minimize edge diffraction in parabolic reflectors

PARABOLIC REFLECTORS ARE often used in small, indoor test ranges to generate plane waves for testing antennas. But the edges of these reflectors generate stray signals that interfere with the desired plane wave and cause measurement errors. These unwanted signals arrive at the test zone at the same time as the desired plane-wave signal and, therefore, cannot be separated by time gating. To minimize these stray reflections, the edges of the parabolic reflector are often modified using serrations or blended rolled edges. Blended rolled edges are superior to serrated edges, but these modified reflectors are costly to manufacture. To overcome this problem, three researchers propose using resistive cards to block the diffractions. Mohamed Sameh A. Mahmoud of Loral Space Systems, (Palo Alto, CA), IEEE Senior Member Teh-Hong Lee, and Walter D. Burnside of Ohio State University (Columbus, OH), performed a study using resistive sheets, or R-cards, as fences to block the edge reflections. The cards are not mounted to the reflectors, but simply mounted at a short distance from the edge of the reflectors to control the direction of the diffracted rays and attenuate their amplitude. See "Enhanced Compact Range Reflector Concept Using an R-Card Fence: Two-Dimensional Case," *IEEE Transactions on Antennas and Propagation,* March 2001, Vol. 49, No. 3, pp. 419-428.

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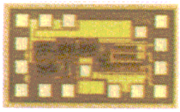
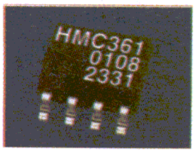
Description		Frequency Range (GHz)	SSB Phase Noise @ 100 KHz	Part Number
÷2	High Efficiency Med. Output Power	DC - 11.0	-148 dBc/Hz	HMC361
		DC - 10.0	-148 dBc/Hz	HMC361S8G
÷2	High Frequency High Output Power	DC - 13.0	-145 dBc/Hz	HMC364
		DC - 12.5	-145 dBc/Hz	HMC364S8G
÷4	High Efficiency Med. Output Power	DC - 12.0	-149 dBc/Hz	HMC362
		DC - 12.0	-149 dBc/Hz	HMC362S8G
÷4	High Frequency High Output Power	DC - 13.0	-151 dBc/Hz	HMC365
		DC - 12.5	-151 dBc/Hz	HMC365S8G
÷8	High Efficiency Med. Output Power	DC - 12.0	-153 dBc/Hz	HMC363
		DC - 12.0	-153 dBc/Hz	HMC363S8G

Divide-by-2

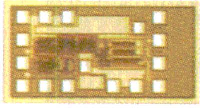


HMC361

HMC361S8G

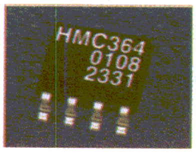


Divide-by-2

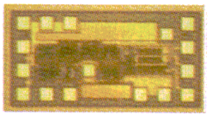


HMC364

HMC364S8G



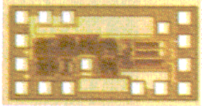
Divide-by-4



HMC362

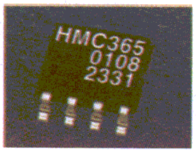
HMC362S8G

Divide-by-4

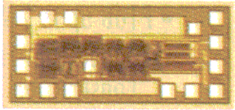


HMC365

HMC365S8G



Divide-by-8



HMC363

HMC363S8G

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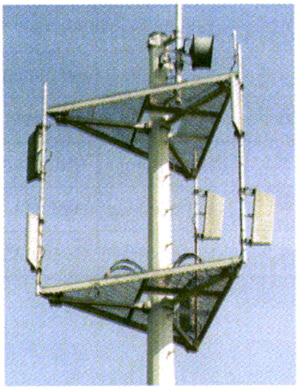

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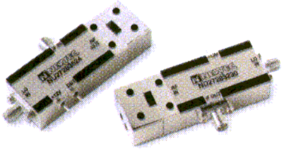


Nextec Microwave & RF, Inc. designs, manufactures and markets high quality components and subsystems for wideband communications applications – worldwide.

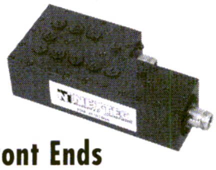
Focusing on LMDS and the new IMT-2000 and UMTS standards, Nextec is positioned to provide you with the design and production know-how to meet your requirements from component to subsystem levels.

Nextec is committed to providing on-time delivery of specification compliant, high quality products at optimum value for your investment.

Filters

Transmit
- 2110 – 2170 MHz
- 0.4 dB Insertion Loss
- -80 dBc Rejection

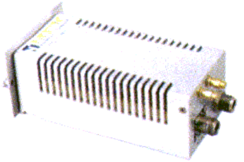
Receive
- 1910 – 1980 MHz
- 0.4 dB Insertion Loss
- -80 dBc Rejection



RF Front Ends

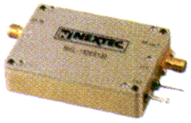
Transmit
- 2110 – 2170 MHz
- 0.5 dB Insertion Loss
- -80 dBc Rejection

Receive
- 1920 – 1980 MHz
- Up to 40 (±1.0) dB Gain
- -90 dBc Rejection



High Power Amplifiers
- 2110 – 2170 MHz
- Up to 45 dBm Output Pow
- Up to 50 dB Gain

Low-Noise Amplifiers
- 1920 – 1980 MHz
- 1.2 dB Noise Figure
- Up to 40 (±1.0) dB Gain



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Emulator Mimics Mobile Communication Channels

A blend of high-quality hardware and control software is needed in modern instrumentation to accurately emulate the characteristics of mobile communications channels.

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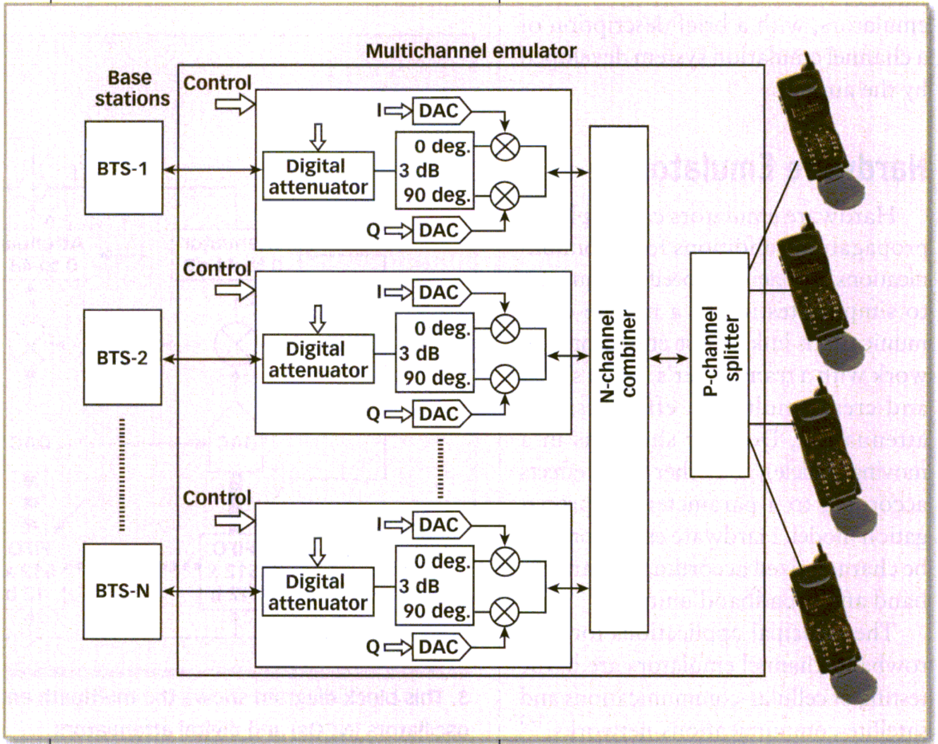
e-mail: cbriso@diac.upm.es.

JOSE I. ALONSO-MONTES
ETSI, Telecomunicacion Dept.
Senales Sistemas y
Radiocomunicaciones, Universidad
Politecnica de Madrid,
Ciudad Universitaria sn, Madrid, Spain,
e-mail: ignacio@gmr.ssr.upm.es.

Mobile communications systems continue to increase in complexity, with higher bandwidths and faster data rates. Because of this complexity, test equipment must be able to emulate the environments experienced by radio channels under a wide range of conditions. This article reviews a special type of test instrument developed for this purpose, the channel emulator. These instruments can create the effects of signal fading, propagation, multipath, Doppler spectrums, and phase variations. They can greatly simplify the testing of a modern wireless communications system by using a time-variant channel, reducing the need for making outdoor measurements.

Modern communications systems, such as digital television, local multipoint-distribution systems (LMDS), and Universal Mobile Telecommunications Sys-



1. This diagram shows a narrowband multi-channel emulator developed for testing channels in cellular systems.

Continued from page 61

tem (UMTS) are in their final stages of development with projected widespread global acceptance. All of these systems employ broadband-communications channels and high data rates, with point-to-multipoint distribution and techniques such as orthogonal frequency-division multiplexing (OFDM) and wideband code-division multiple access (WCDMA) to overcome multipath problems.

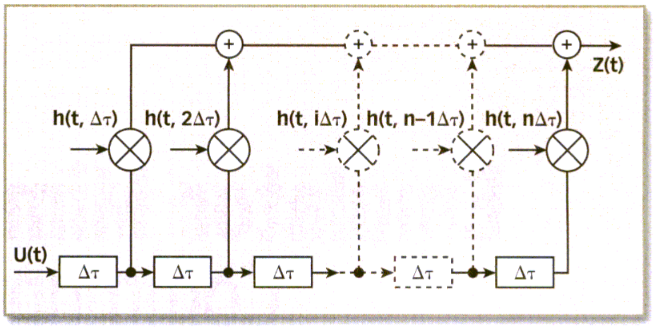
New test tools are required to fully evaluate these emerging communications systems and, during the last few years, many hardware-based communications channel emulators have been developed by several test-equipment manufacturers, including Agilent Technologies (Santa Rosa, CA), Noise Com, Inc. (Paramus, NJ), and Spirent Communications (formerly Telecom Analysis Systems, Eatontown, NJ).

These test systems can emulate a mobile propagation channel by using a sophisticated RF signal-processing chain controlled by an embedded or external computer running a software propagation model. What follows is a review of some of the hardware and software capabilities, requirements, and applications of modern channel emulators, with a brief description of a channel emulation system developed by the authors.

Hardware Emulators

Hardware emulators can duplicate propagation conditions for a communications channel at a specific frequency, to simplify testing of a mobile-communications link. These emulators can work with a transmitter's (Tx's) signal and create multipath effects, signal attenuation, Doppler shifts (as in a moving vehicle), and other signal effects according to a parameterized propagation model. Hardware emulators can be characterized according to narrowband and broadband units.

The principal applications for narrowband channel emulators are in the testing of cellular-communications and satellite-communications networks.[1-3] These emulators are specially focused in the reproduction of a network with several base stations (or satellites) and several mobile terminals. The objective of the test equipment is to simulate handovers, interference, power control, and any other functionality of the network. An example of this kind of narrowband emulator system is shown in **Fig. 1**.



2. This block diagram shows the multipath propagation model used in a channel emulator.

The basic architecture of a narrowband channel emulator is fairly simple, and only requires some fast digital attenuators, in-phase/quadrature (I/Q) modulators, and vector generators to reproduce amplitude and Doppler shifts for several communications channels. Although the RF components are analog, they operate through digital interfaces. The control of the whole system is performed through a personal computer (PC) with a propagation model.

In a broadband system, however, it is necessary to split an input signal into several rays to simulate propagation through different signal paths from a t Tx to a receiver (Rx). The transfer function of this broadband system is modeled according to the schematic diagram of **Fig. 2**. In this model, the propagation channel is created by splitting an input signal into six to 12 taps, and controlling the amplitude, frequency, phase, and delay of each resulting signal.

This type of model is considerably more complex than a narrowband emulator, and requires sophisticated hardware for high resolution over broad bandwidths. A main difficulty in this model is the dynamic generation of long delays. In this model, variable delay lines are achieved through digital circuits. The input signal is sampled with an analog-to-digital converter (ADC) and output data are saved in a first-in, first-out (FIFO) memory for

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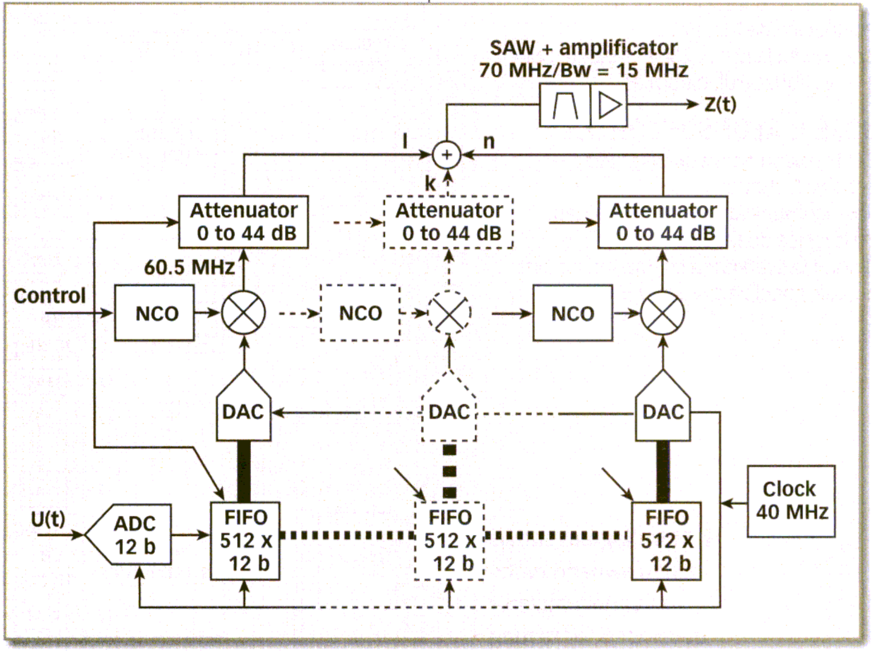

3. This block diagram shows the multipath emulator, with numerically controlled oscillators (NCOs) and digital attenuators.

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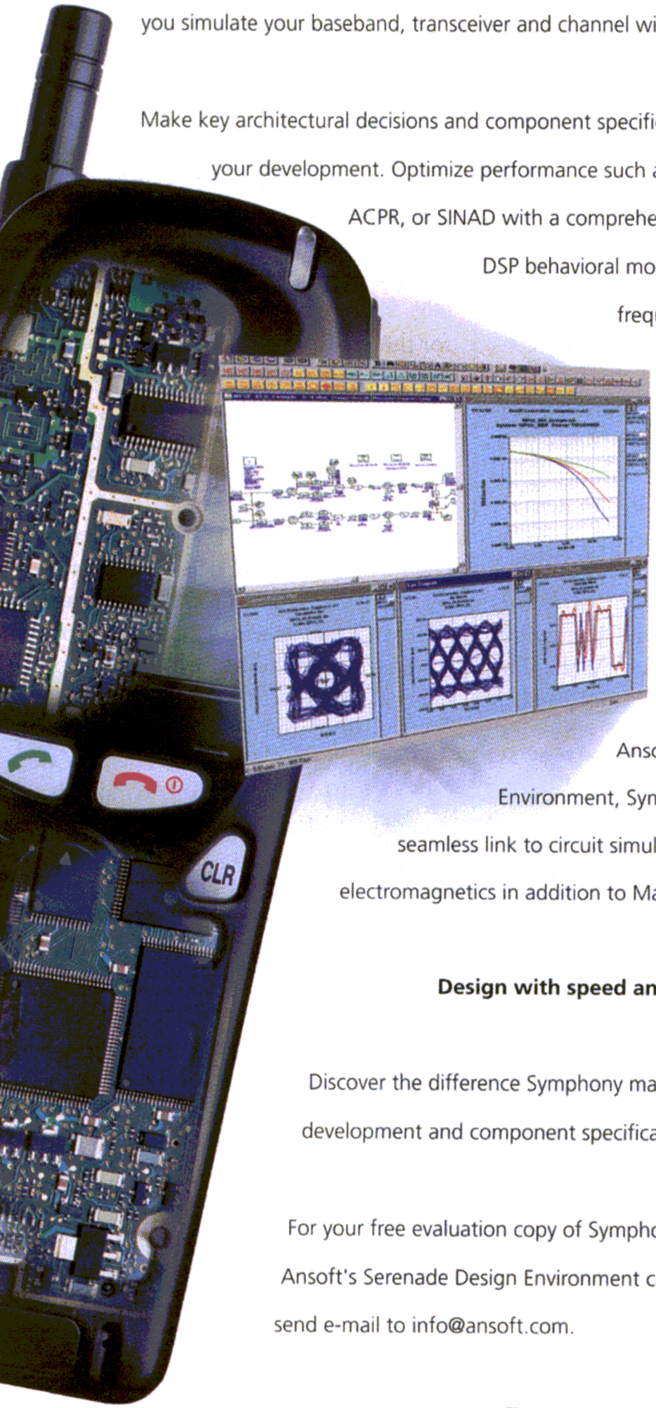

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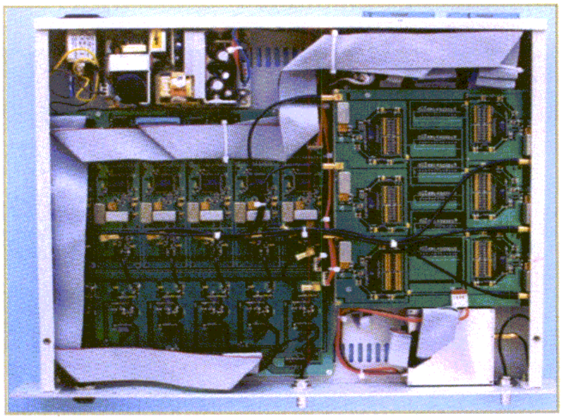
Continued from page 62

the desired time delay and then converted back to analog form. This process must deliver high resolution for six to 12 signal paths. This process must be performed with high resolution for the six to 12 paths. For this reason, the input signal must be converted to a low intermediate frequency (IF) [8 to 10 MHz] and sampled with a 12-to-14-b, high-speed ADC.

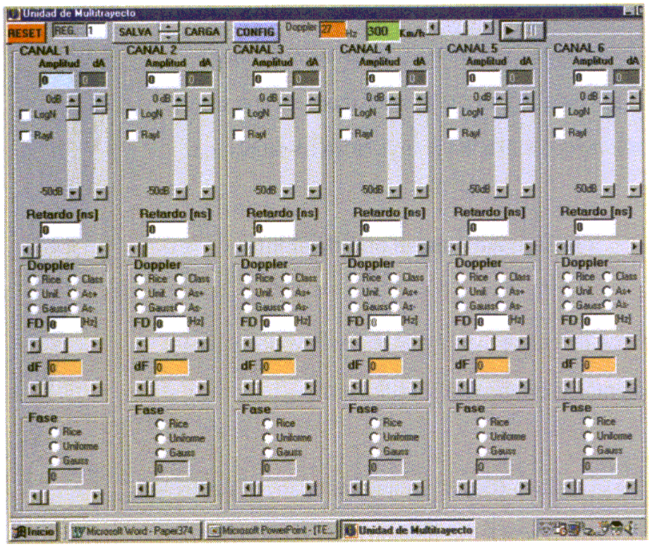
Another problem with the broadband model is that all channel parameters must change over a large range, and at a high rate to reproduce the time-variable channel. That is why the digital processors must be fast and the RF analog circuits must provide a wide dynamic range. Different propagation requirements may involve amplitude changes in excess of 50 dB, Doppler shifts of hundreds of hertz, and delays from a few nanoseconds to several microseconds.

A channel emulation system is controlled with a PC and a special software program. The software must calculate statistical and deterministic variations of each channel according to the speed of the mobile unit, the simulation frequency, the environmental conditions, and other factors. For example, requirements for different channel parameters include simulation of amplitude for line-of-sight propagation, with log-normal distributions having 2-to-10-dB standard deviation; non-line-of-sight propagations with Rayleigh distributions having a K factor of 5 to 40 dB; Doppler shifts in excess of 1000 Hz to accommodate transmission frequencies from 0 to 10 GHz; and vehicle (mobile-unit) speeds of 0 to 500 km/hr with wide variations in distributions. These include Rayleigh, uniform, log-normal, and asymmetrical spectrums that are used.[4] Control of phase from 0 to 360 deg. with a variety of different distributions (most often uniform distributions) is another; along with control of delay times to accommodate most propagation environments, typically 30 ns (9-m transmission distance) to 15 μs (4.5-km transmission distance).



4. This photograph illustrates the tight integration of components in the six-channel multipath unit.

The authors have developed a complete six-channel emulator that includes broadband frequency conversion, wide emulation bandwidth, and full control of multipath effects. The emulator system includes a frequency converter and a multipath unit. The frequency converter consists of a dual- frequency downconverter/upconverter for use from 800 to 2000 MHz. An input signal is first converted to an IF of 9 MHz that can be used by the multipath unit, before reconversion back to the 800-to-2000-MHz range. The frequency converter must provide high-quality frequency-conversion steps, since it is necessary to amplify, filter, and translate (in frequency) an input signal several times prior to producing the desired output signal. As a result, any noise contributions can result in distortion of the output signals. For this reason, the frequency converter must be precisely built for low distortion while maintaining an IF bandwidth of 15 MHz centered at 9 MHz. The phase noise of all oscillators used in the unit is also critical to achieving the desired final converter low-noise performance.



REG. 1

Doppler 27 Hz

300 Km/h

5. Control of the multipath unit is performed through this on-screen software control window.

The multipath unit is based on the use of discrete blocks. It has six or more channels each with maximum 15-MHz bandwidth and high-resolution digital control of every emulation parameter **(Fig. 3)**. The principal characteristics for the multipath unit include a choice of 6 to 12 channels, an emulation channel bandwidth of 10 to 15 MHz, total amplitude control per channel of 50 dB that is adjustable in 0.1-dB increments, a Doppler control range of ±10 kHz that is adjustable in 0.1-Hz steps, a phase-control range of 360 deg. that is adjustable in 1-deg. steps, and a total delay range of 0 to 12,500 ns with 25-ns resolution.

The first of the discrete blocks is a six-channel delay unit. It features a high-quality input ADC with 12-b resolution. The ADC operates at 40 MSamples/s to sample the 9-MHz input IF. The output data are sent to a FIFO memory bank. Delays are created by storing the data in these memories, and shifting data from cell to cell during each sampling period. The memory bank has six concatenated outputs to create six output signals. The delay of the first is (1, the second is (1+ (2 , etc., and the duration of the delay of each channel is controlled by the computer with the clock of the input ADC and FIFO **(Fig. 4)**.

The FIFO memory bank

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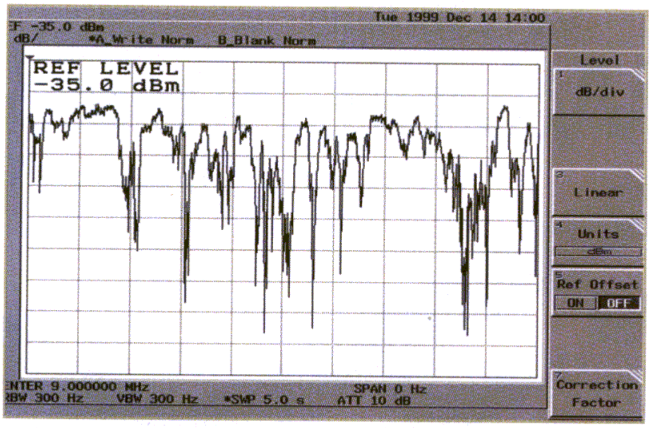


6. This on-screen display shows the plot of a channel with severe multipath distortion recorded at a modern mobile speed (low Doppler shift) and measured at the intermediate frequency.

has six blocks of 512 × 12 b each. With a sampling clock frequency of 40 MSamples/s, this results in 25-ns delay resolution and a maximum delay of 12,800 ns per stage. This translates into propagation-distance resolution of 8 m with a maximum equivalent transmission distance of 10 km. These values are adequate for all outdoor environments and also for large indoor areas.

The output of each channel is converted from digital to analog with a 12-b digital-to-analog converter (DAC) and multiplied by the transfer function of each path. This multiplication is performed with a high-quality analog multiplier.

The second important discrete block generates the propagation function for each channel. This block must control the frequency, phase, and amplitude variations of the input signal. There are several solutions for this function, and the most classical uses I/Q modulators controlled with DACs and a digital signal processor (DSP) to calculate the variations of each channel.

In the case of the authors' channel emulator, propagation is achieved by using an advanced version of a numerically controlled oscillator (NCO). This device includes a digital oscillator and I/Q modulator on a single chip. The NCO makes it possible to digitally generate a signal with frequency that can be controlled very accurately. The NCO uses an arithmetic logic unit (ALU) and a look-up read-only memory (ROM) to access amplitude values for a sinusoidal function. The phase can also be controlled with high precision adding a phase register to the output of the frequency ALU.

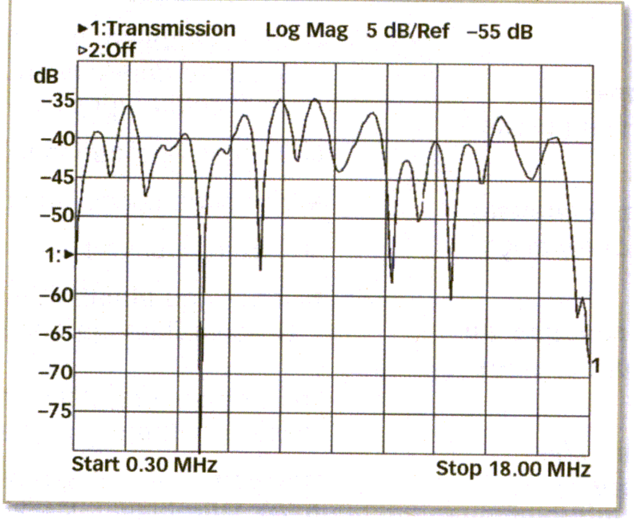
Typically, these devices use 20-b internal processing, with 32 b for frequency control and 12 b for phase. The frequency resolution is 0.01 Hz, the phase resolution is 0.1 deg., and the amplitude resolution is 0.1 dB, so it is possible to generate accurate Doppler shifts, amplitude fading, and phase variations.

The output of each NCO is multiplied by the output of each delay and the contributions of the NCOs are combined with an analog adder. The result is a system with a very-flat frequency response and more than 50 dB of spurious-free dynamic range (SFDR).

The channel emulation system is controlled by a PC through a 48-line parallel interface and a program running under the Windows operating system. The software controls the parameters of each signal tap, including amplitude, frequency, phase, and delay characteristics, and makes it possible to apply one or several statistical variations to any one of the channels. Each channel is modeled by applying the desired delay and statistical variations to the amplitude, frequency, and phase of each tap. The software employs a simple control interface where values can be entered by computer keyboard or mouse **(Fig. 5)**.

Input parameters include frequency of operation and speed of the mobile unit. These data are used to calculate the speed of variation of the channel and the maximum Doppler shift. The remaining control parameters are programmed by the user with data available from measurement or models. One of these steps, for example, is to program the delay profile of a channel. As noted previously, this delay is constant for a particular emulation period, depending upon the environment where the mobile unit is located. The emulator system contains suitable memory to store different delay profiles when the mobile unit is moving from one environment (for example, a city) to another environment (such as open ground).

The mean value of amplitude of each channel is programmed using data from the power-delay profile, and it is possible to apply several statistics to each channel. Typically, a Rayleigh distribution is used to model fast variations due to multipath conditions while a log-normal distribution is used to model the slower variations of the principal ray.



7. Channel frequency response is shown here, using IF measurements (1 to 16 MHz). The channel emulation featured moderate multipath propagation with a dominant ray.

The Doppler spectrum has six possible distributions: classic, uniform, Gaussian, Ricean, positive asymmetric, and negative asymmetric. It is also possible to program a fixed deviation of the mean value of the frequency of a signal tap to simulate a constant Doppler shift. The channel emulation phase can be programmed using three statistical distributions: uniform,

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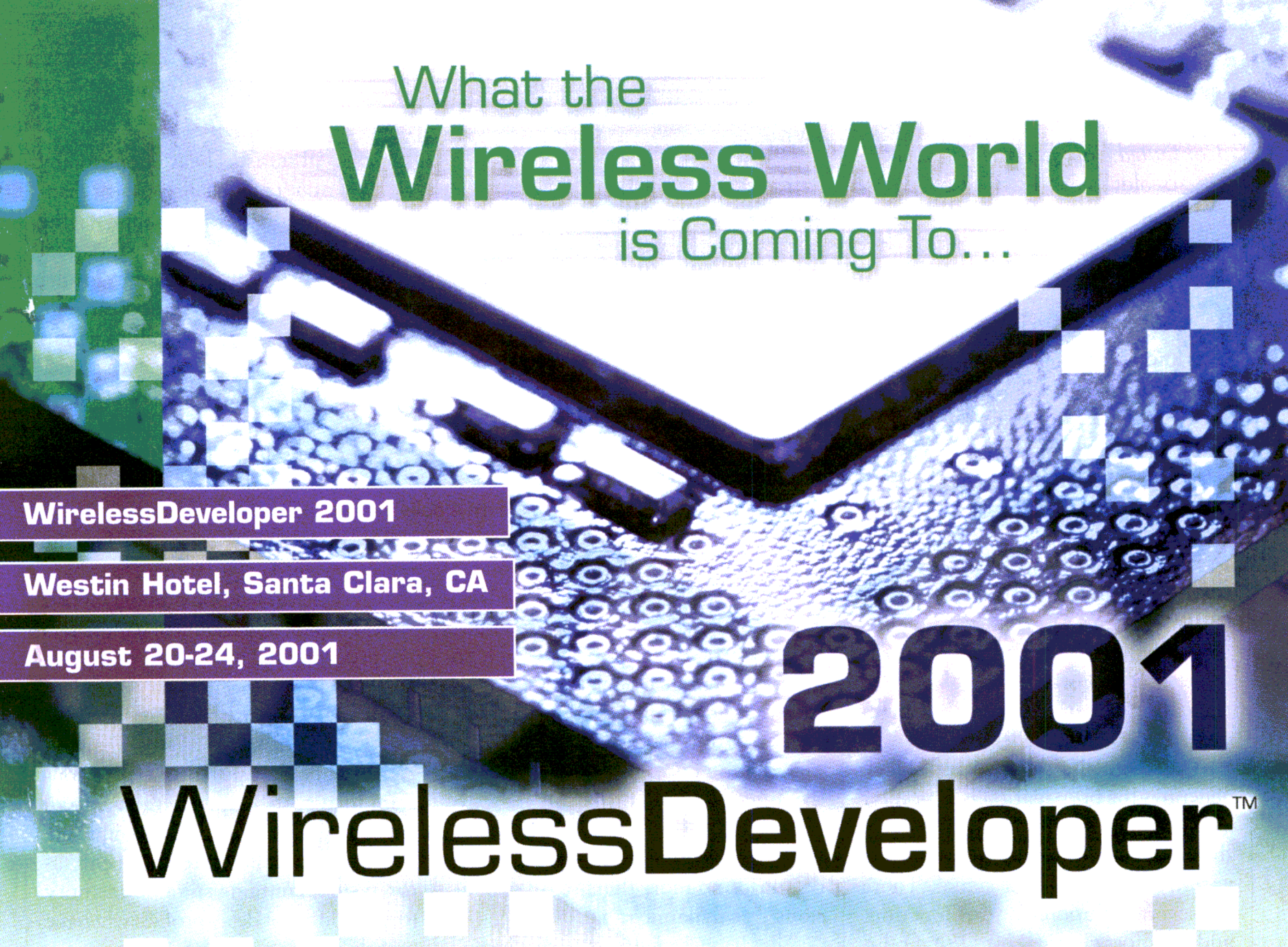

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IE3D Simulation Examples and Display

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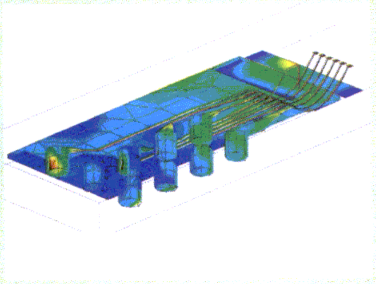
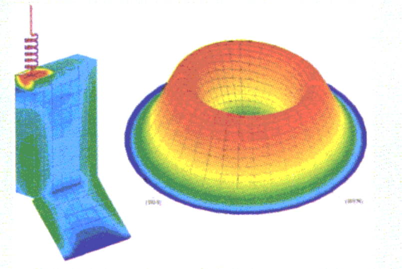
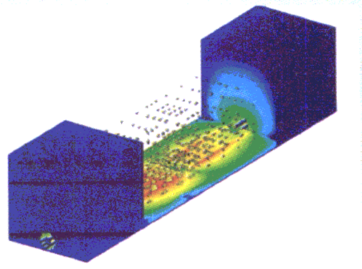


The current distribution and radiation pattern of a handset antenna modeled on IE3D

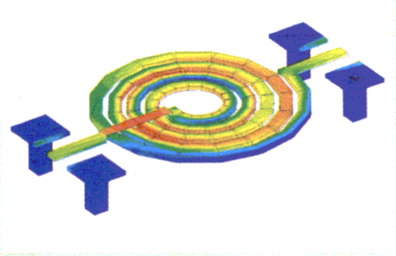


FIDELITY Examples

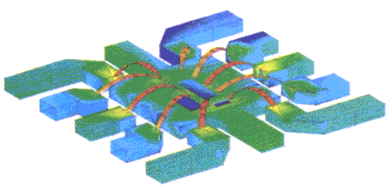
The near field and Poynting vector display on a packaged PCB structure with vias and connectors



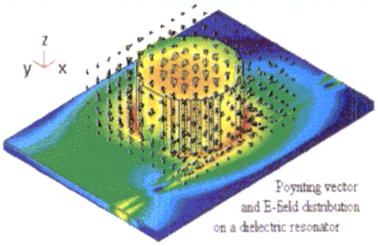
IE3D modeling of a circular spiral inductor with thick traces and vias



IE3D modeling of an IC Packaging with Leads and Wire Bonds



FIDELITY modeling of a cylindrical dielectric resonator and the Poynting vector display



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Design High-Order PLLs

This article presents a linear model of a PLL with various types of lowpass filters, and describes a phase-stability criterion that can be used to simplify calculations.

Phase-locked loops (PLLs) are among the most fundamental technologies used in modern telecommunication systems. The optimization of a PLL very often boils down to calculating an adequate lowpass loop filter, which involves a trade-off among several conflicting requirements. This article describes the issues that one must consider when developing the loop filter. Part 1 describes the development of fourth-order, second-type PLL loops. Part 2 focuses on the development of "equal-pool" filters of any order, and may be treated as the generalization of the most-often-used practical cases.

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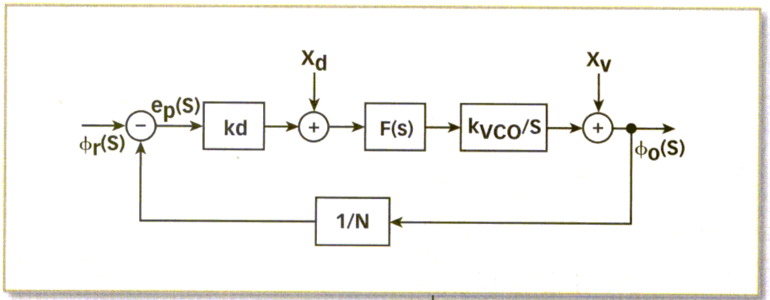

1. This is a simplified diagram of a single-loop synthesizer.

Part 1

A simple, low-frequency, negative-feedback linear loop is the PLL model most often used in engineering practice. It describes the stability conditions as well as frequency and transient-time solutions for small disturbances near the steady-state working point.

Figure 1 shows a simplified diagram of a single-loop synthesizer. In this figure, jr is the reference (input)-phase signal, ϕ_0 is the voltage-controlled-oscillator (VCO) output phase, e_p is the phase error, x_d is the phase detector's spurious signals, x_v is the VCO's noise and distortion, k_d is the phase-detector constant, F(s) is the lowpass-filter transmittance, k_{vco} is the VCO constant, and N is the frequency-divider ratio.

K_d and F(s) depend on the specific type of phase detector. The phase detector is the main cause of nonlinearity in

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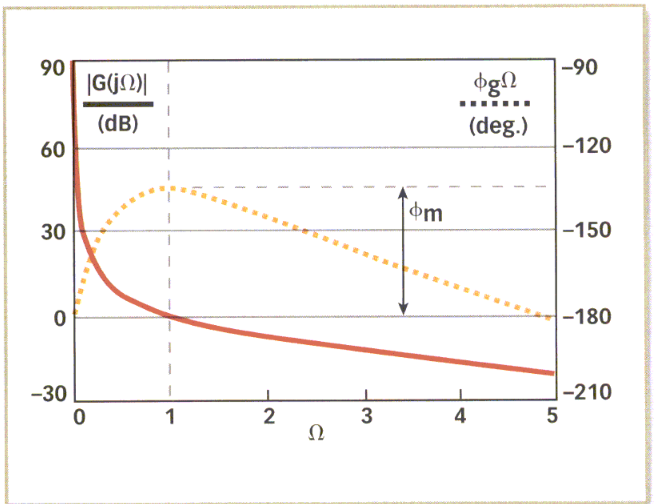

2. This is an example of an open-loop transfer function with filter (1) for additional conditions (12).

a PLL. For a limited e_p range, one may approximate it as linear. In this linear range, one uses the average value of its output. This average value is produced by the lowpass filter of the loop and can be considered as the phase detector's output with additional spurious signal, x_d. For charge-pump phase detectors, the problem is somewhat more complicated. A better model would be "z" rather than a Laplace transform[3] but, in practice, the model most often used is the previously mentioned approximation, where averaging requires the use of an additional integrator and leads in a natural way to the second-type loop. The loop "order" determines the number of open-loop transfer-function poles. The loop "type" determines the number of these poles that decay to zero.

In a synthesizer application, where requirements for characteristics such as frequency range, spectral purity, and transient time are imposed arbitrarily, the only way to meet these requirements is to calculate the appropriate lowpass filter F(s). Meeting the bandwidth requirement of this filter is always a trade-off among competing characteristics. For instance, phase detector x_d attenuation, which demands narrower filters, competes with reduction of VCO noise x_v as well as short transient times, which require higher-frequency bandwidth. For a more-accurate approach, the noise generated by reference sig-

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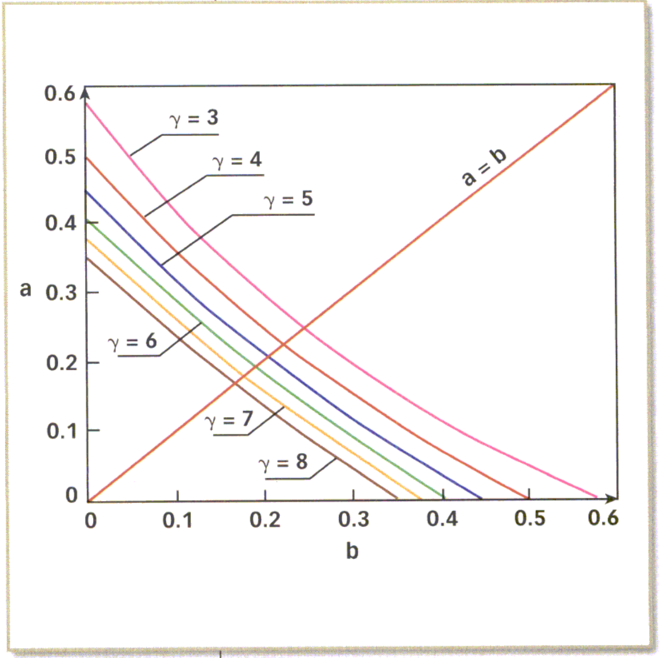

3. This figure shows the relationship between a and b for some values of γ.

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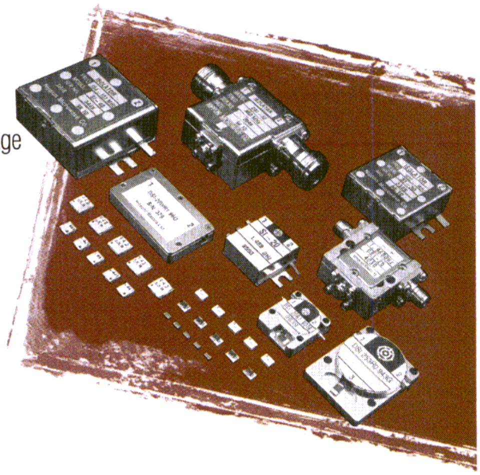

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nals, dividers, and phase detectors should be also taken into consideration. Better performance leads to higher loop-filter orders and generally requires a numerical method to find the optimal solution.

One can describe a second-order loop using two elementary parameters: damping factor and natural-loop frequency.[2,4] Applying a loop filter with one pole and one zero, it is possible to independently select the loop bandwidth, defining stability, and damping factor. The effectiveness of phase-detector spur attenuation in this loop is not very good.

Fourth-Order Loop

Adding another pole and zero to the integrator creates a second-order filter, forming a third-order type-two PLL. Stability in this loop is described by the phase margin in unity open-loop gain. For better x_d attenuation, a filter with an additional pole is often used, creating a fourth-order type-two loop. In practice, this pole is set approximately and the next whole filter is individually adjusted for acceptable phase margin. An analysis begins with a third-order loop filter, described as:

$$F(s) = \frac{1 + Ts}{Ds(1 + As)(1 + Bs)} \qquad (1)$$

This results in a fourth-order type-two PLL. The closed-loop transfer function Fc for **Fig.1** can be written as:

$$F_c(s) = \frac{\varphi_o(s)}{\varphi_r(s)} = \frac{NG(s)}{1 + G(s)} \qquad (2a)$$

where

$$G(s) = \frac{k_d k_{vco}}{Ns} F(s) \qquad (2b)$$

and

$$F_x(s) = \frac{\varphi_o}{x_d} = \frac{F_c(s)}{k_d} \qquad (2c)$$

G(s) is the open-loop transfer function. For the filter described in Eq. 1,

Continued on page 74

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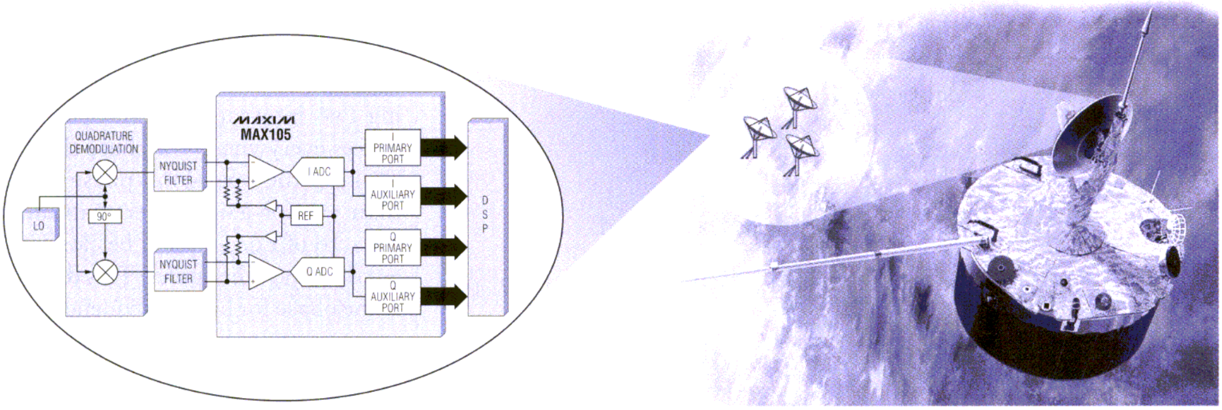

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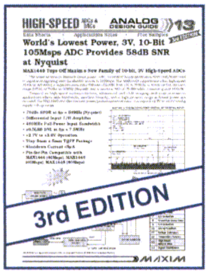
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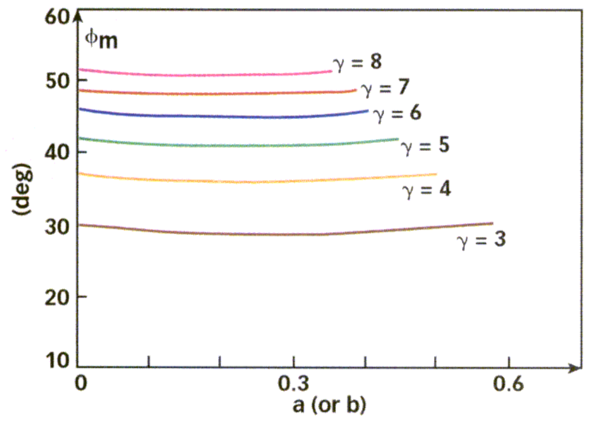


4. Phase margin ϕ_m versus a(b) depending on γ can be seen here.

Continued from page 72

the closed-loop function $F_c(s)$ is thus given as:

$$F_c(s) = \frac{k}{D}$$

$$1 + Ts\ /\ ABs^4 + (A + B)s^3 +$$

$$s^2 + \frac{kT}{ND}s + \frac{k}{ND}$$

$$\text{where } k = k_d k_{vco} \qquad (3)$$

To find the stability conditions, use the Hurwitz-Lienard criterion for the denominator of $F_c(s)$. Writing the Hurwitz matrix of the fourth-order polynomial, the condition for all poles left plane of s reduces to check only one determinant:

$$\begin{vmatrix} A + B & AB & 0 \\ \frac{kT}{ND} & 1 & A + B \\ 0 & \frac{k}{ND} & \frac{kT}{ND} \end{vmatrix} > 0 \qquad (4)$$

After some elementary transformations, one can write Eq. 4 as:

$$T(A + B) - (A + B)^2 >$$

$$\frac{kT^2}{ND}AB \qquad (5)$$

The right side of Eq. 5 is higher than zero since the sign of k and D should be the same (for negative feedback) and N, T, A, and B must be positive. Involving new value γ, one can write the first term:

$$\gamma > 1$$

$$\text{where } T = \gamma(A + B) \qquad (6)$$

From Eq. 5, the stability condition can be written as:

$$\frac{\gamma - 1}{\gamma^2}\frac{D}{AB} > \frac{k}{N} \qquad (7)$$

This is the global-stability condition for the fourth-order loop. The condition described by Eq. 6 is clear. Having two integrators in an open loop makes everywhere $-\pi$ phase shifting. To keep the open-loop phase higher than $-\pi$ for gain higher than unity, the zero of Eq. 1 should be closer to s = 0 than the other poles. This decreases the phase for higher frequencies and it means that the phase of the open loop should be maximum **(Fig. 2)**.

Generally, a PLL is nonlinear. One can talk about its stability only at a particular point on its phase space ("phase" has another meaning here, specified by state variables). But depending on initial conditions, this point may never be achieved. So the usefulness of this formula is limited. For stability, more "reserve" is required. In practice, the open-loop criterion is used with adequately high-phase margin.

Now A, B, T, and D must be assigned. The loop frequency, ω_0, is defined by the following condition:

$$|G(j\omega_o)| = 1 \qquad (8)$$

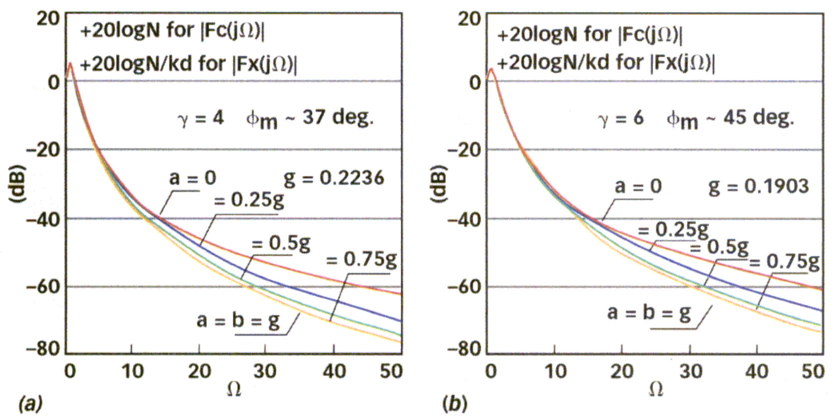
It is very useful to treat ω_0 as one of the fundamental-loop-design parameters. In particular, one can normalize the frequency transmittances to ω_0 to simplify these expressions. From Eqs. 1, 2, and 8, one can write:

$$D = \frac{k}{N\omega_0^2}$$

$$\left|\frac{1 + jT\omega_0}{(1 + jA\omega_0)(1 + jB\omega_0)}\right| \qquad (9)$$

And substituting:

Continued on page 76



5. This shows normalized frequency dependence of ϕ_o on ϕ_r and x_d for two values of γ.

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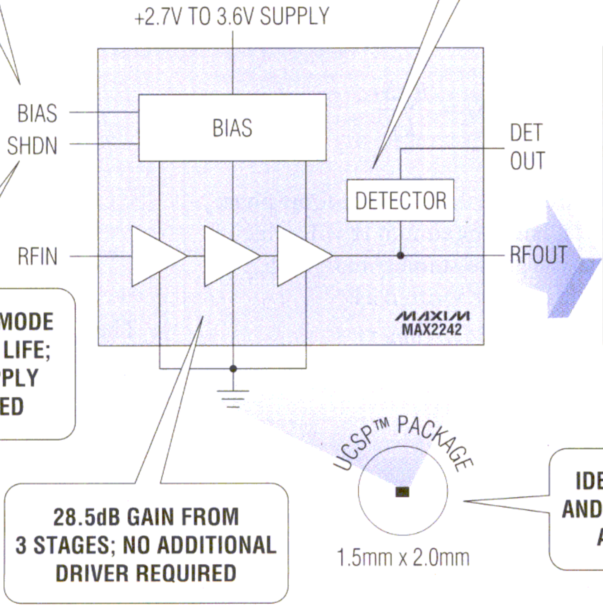

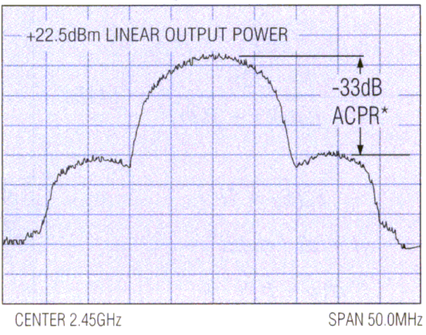

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Continued from page 74

$$S = \frac{s}{\omega_0} \qquad \Omega = \frac{\omega}{\omega_0}$$

$$A = \frac{a}{\omega_0} \qquad B = \frac{b}{\omega_0} \qquad T = \frac{\tau}{\omega_0}$$

$$D = \frac{k\sigma}{N\omega_0^2}$$

$$\text{where} \quad \sigma = \sqrt{\frac{1+\tau^2}{(1+a^2)(1+b^2)}} \qquad (10)$$

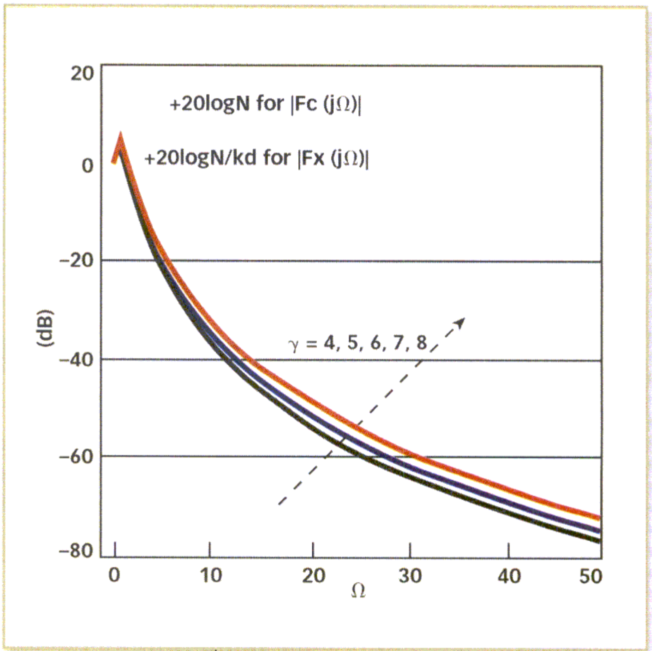
Equations 2 and 6 can be rewritten as:

$$\tau = \gamma(a+b) \qquad (11a)$$

$$G(j\Omega) = |G(j\Omega)|e^{j\varphi_g(\Omega)} = -\frac{1}{\sigma\Omega^2}\frac{1+j\Omega\tau}{(1+j\Omega a)(1+j\Omega b)} \qquad (11b)$$

$$F_c(S) = N \; 1 + \tau S \, / \, \sigma abS^4 + \sigma(a+b)S^3 + \sigma S^2 + \tau S + 1 \qquad (11c)$$

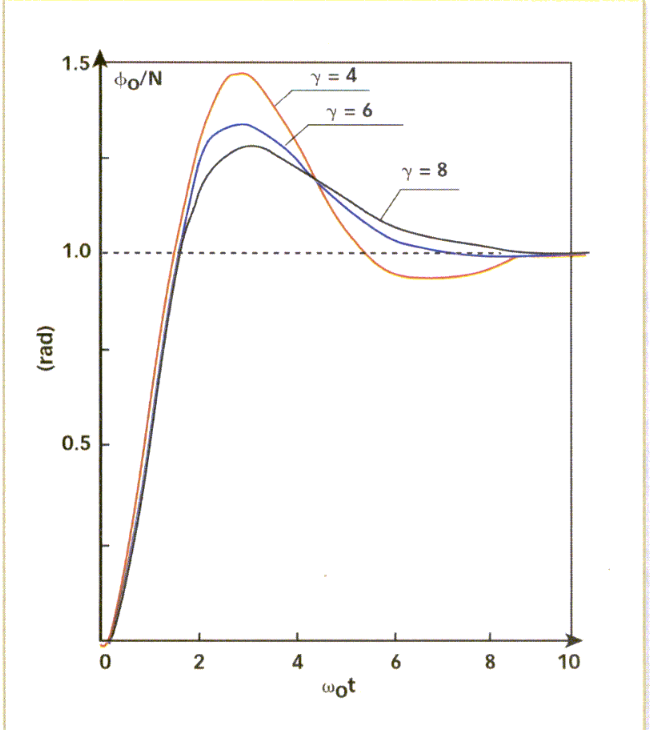
6. This shows normalized frequency dependence ϕ_o on ϕ_r for a = b and some values of γ.



$$F_x(S) = \frac{F_c(S)}{k_d} \qquad (11d)$$

As in ref. 1, the open-loop phase, ϕ_g Ω, has a maximum $\Omega = 1$, which is also the phase-stability margin ϕ_m. All of this can be written as:

$$\varphi_m = \arctan(\tau) - \arctan(a) - \mathrm{arctg}(b) \qquad (12a)$$



7. This shows normalized output-phase response for reference $\Delta\phi$ step (a = b, input signal $\phi_r = \Delta\phi/s$).

$$\frac{d\varphi_g(\Omega)}{d\Omega} = \frac{\tau}{1+\tau^2} - \frac{a}{1+a^2} - \frac{b}{1+b^2} = 0 \quad \text{for} \quad \Omega = 1 \qquad (12b)$$

These relationships are shown in **Fig. 2**.

From Eq. 12b, making use of Eqs. 6 and 10, one can perform dependence a and b on γ as in **Fig. 3**. All of the curves in Fig. 3 are symmetrical to line a = b and one can consider only parameter a, (or b) from zero to a = b (for instance, when a = 0, $-b^{-1}$ is a pool in a second-order filter). Increasing a to a = b, one gets a third-order filter with a double pole $-a^{-1}$. From Eq.12b, the extreme values of a and b are:

$$a = 0 \Rightarrow b = \frac{1}{\sqrt{\gamma}} \qquad (13a)$$

Figure 4 shows phase margins (Eq. 12a) for some values of γ.

With a small error, γ describes phase margin ϕ_m. For the case where $\gamma = 6$, ϕ_m ~ 45 deg., so the stability also can be described by γ. For Ω >> 1, Fc (jΩ) ~ NG(jΩ), which means that the attenuation of x_d directly depends on loop-filter F (jΩ). **Figure 5** shows some loop functions for two stability factors of γ

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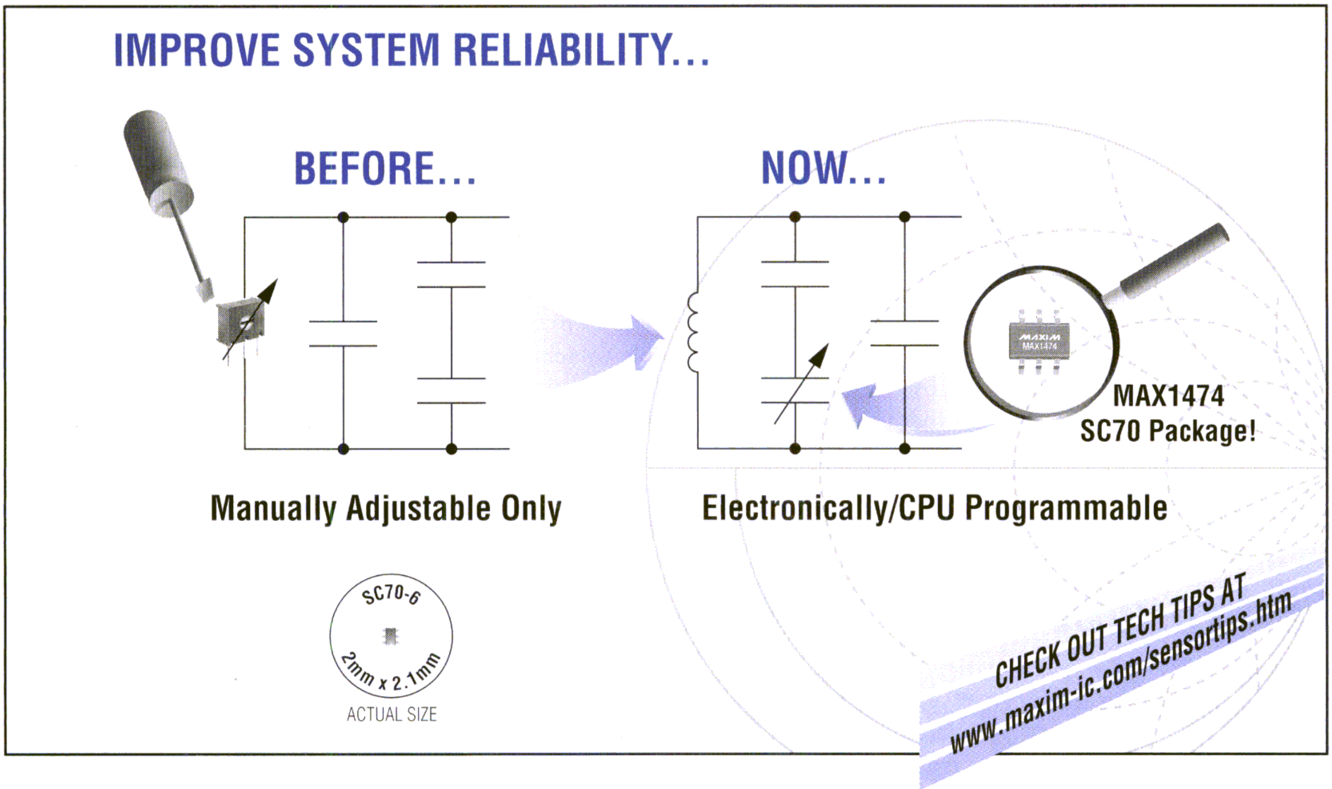
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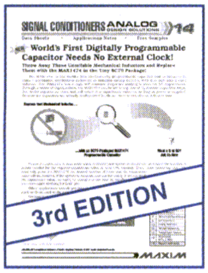
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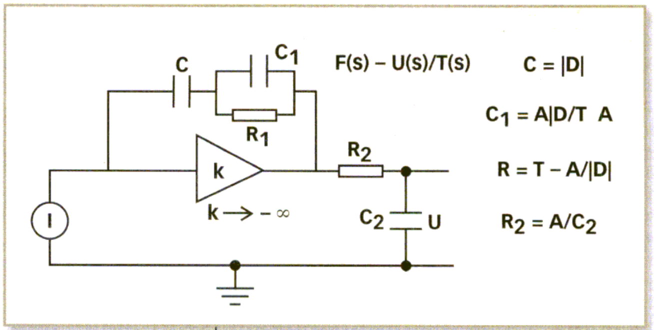
and some values of a(b). For $\Omega > 5$, the most attenuation is for $a = b = g$. Taking $a = b$ as most favorable in this case, the frequency relation mentioned before for some values of γ is presented in **Fig. 6**.

Less-stability margin leads to longer transient times and higher overshoots of output phase. Some responses of output phase, ϕ_0, for input reference $\Delta\phi$ phase step are shown in **Fig. 7**.



8. This shows one realization of F(s) for current input sources. C2 is taken freely.

Loop-Filter Calculations

Here, one can take the equal-pole $a = b$ case since it provides better x_d attenuation and is easy to calculate. When loop parameters k_d, k_{vco}, and N are established, one can determine F(s) by choosing loop frequency ω_0 and the phase margin. Taking an arbitrary stability factor, for instance $\gamma = 6$ ($\phi_m \sim 45$ deg.), using Eqs. 11a and 13b yields τ and $a = b$. Using a particular value of ω_0, real filter parameters T, A, and D can be calculated from Eq. 10. One example of an active-filter realization is shown in **Fig. 8**.

From the previous discussion, one can see that fourth-order loop calculations for active filters are quite simple. The only problem with the $a = b$ condition is that it is impossible to achieve an exact passive realization of this filter using only resistors and capacitors. So in this case, the poles must be slightly extended. One practical method of achieving an approximate realization would be to build the first part of filter F(s) with only one of both poles $-a^{-1}$ (similar to a typical second-order filter), and to add another $RC = A$ section under the condition that the additional capacitance should be much less than that indicated by the previous calculation. The disadvantage of this is the high value of the last resistor R, which may cause too much noise in the VCO's input. Practically, to achieve the required phase margin, it may be necessary to adjust some of the component values in such a passive realization. Since k_{vco} is generally a

Continued on page 80

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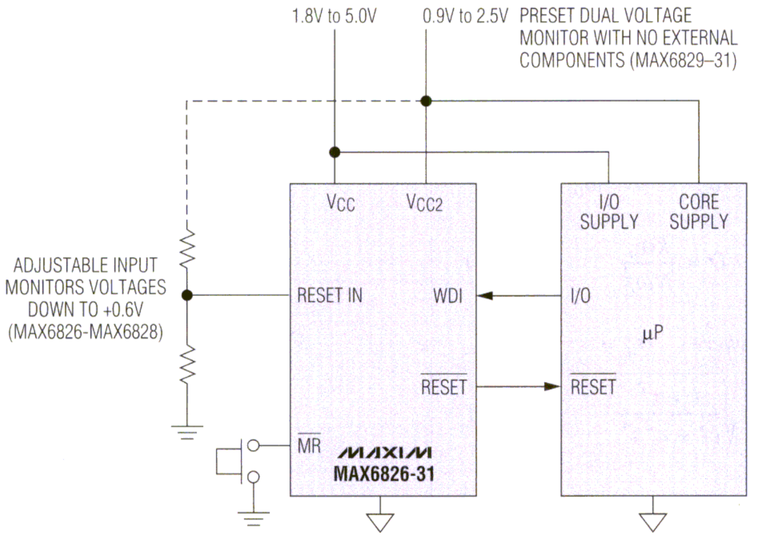

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nonlinear function of the control voltage, one should check the stability margin in worst case, which often occurs as a highest k_{vco} and lowest N (Eq. 7).

Thus, the only design parameter in this case is the loop frequency, ω_0, and, in a limited range, the stability factor γ.

Part 2

The next loop-filter type that may be easily implemented using a phase-margin stability criterion is described by the function:

$$F(s) = \frac{1 + Ts}{Ds(1 + As)^n}$$

$$n - natural\ number \qquad (14)$$

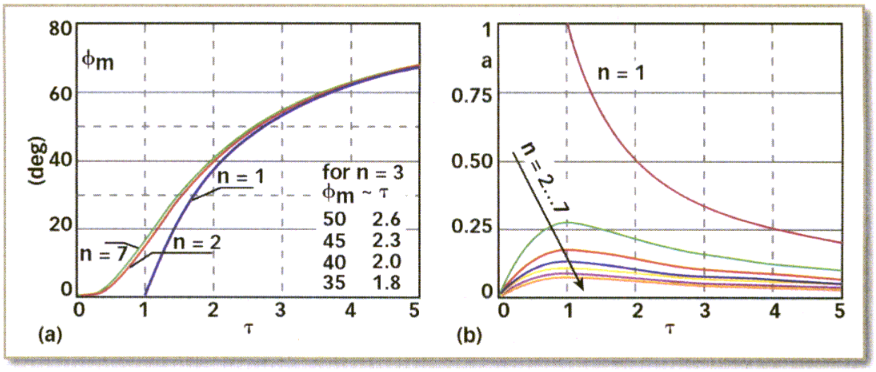
This may be treated as a generalization of the second-order (n = 1) and third-order (n = 2) filters analyzed earlier. Using Eqs. 2 and 8, one can normalize the filter parameters in the same way as for a fourth-order PLL:

$$T = \frac{\tau}{\omega_0} \qquad A = \frac{a}{\omega_0} \qquad (15a)$$

$$D = \frac{k\sigma_n}{N\omega_0^2} \qquad (15b)$$

$$where \qquad \sigma_n =$$

$$\sqrt{\frac{1 + \tau^2}{(1 + a^2)^n}} \qquad (15c)$$



9. This shows stability phase margin ϕ_m versus τ. (a). The relation between a and τ can also be seen (b).

With Ω and S (Eqs. 2 and 10), some loop-transfer function can be written as:

$$G(j\Omega) =$$

$$-\frac{1 + j\tau\Omega}{\sigma_n\Omega^2(1 + ja\Omega)^n} \qquad (16a)$$

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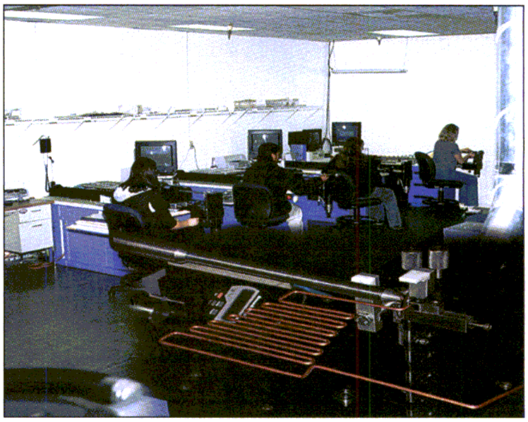

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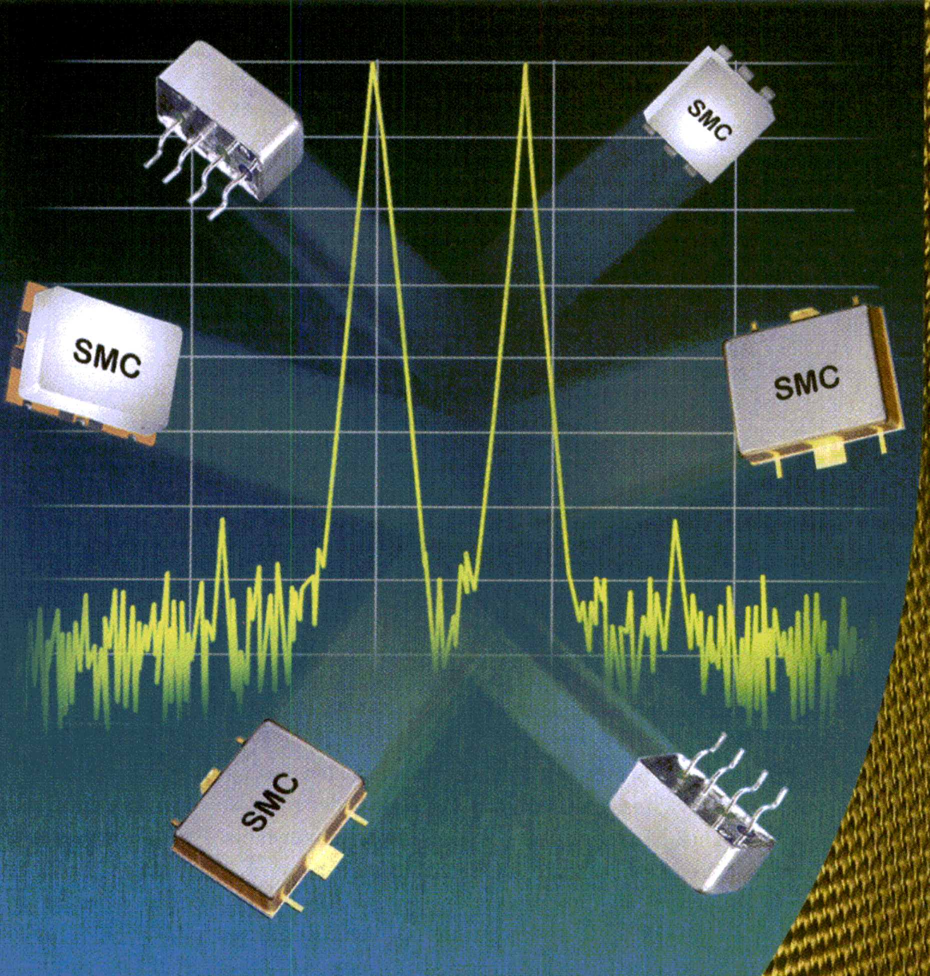

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$$F_c(S) = N\;1 + \tau S\,/\,\sigma_n S^2(1 + aS)^n + \tau S + 1 \qquad (16b)$$

$$e_p(S) = \sigma_n S^2(1 + \tau S)^n\,/\,\sigma_n S^2(1 + aS)^n + \tau S + 1 \qquad (16c)$$

The phase-stability condition, similar to Eq. 12, can now be expressed as:

$$\varphi_m = \arctan(\tau) - n(\arctan(a)) \qquad (17a)$$

$$\frac{d\varphi_g(\Omega)}{d\Omega} = \frac{\tau}{1+\tau^2} - n\frac{a}{1+a^2} = 0 \quad \text{for } \Omega = 1 \qquad (17b)$$

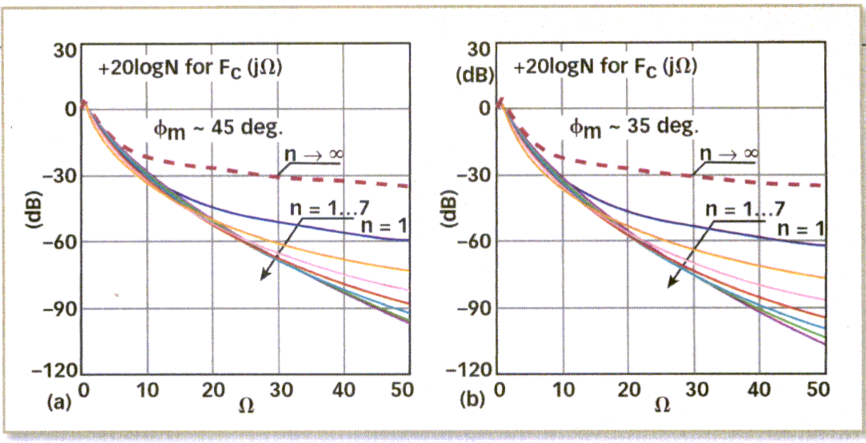
From Eq. 17b, the requirement for shape of ϕ_g (shown in Fig. 2), the relationship between t and a can be described as:

$$a = n(1 + \tau^2) - \sqrt{n^2(1 + \tau^2)^2 - 4\tau^2}\,/\,2\tau \qquad (18)$$

This is a general relationship, including the second- and third-order filter mentioned earlier, whose root one should always take as a positive value. Now one can describe direct relationships between ϕ_m and τ without additional stability factors, presented in **Fig. 9a,** for some values of n.

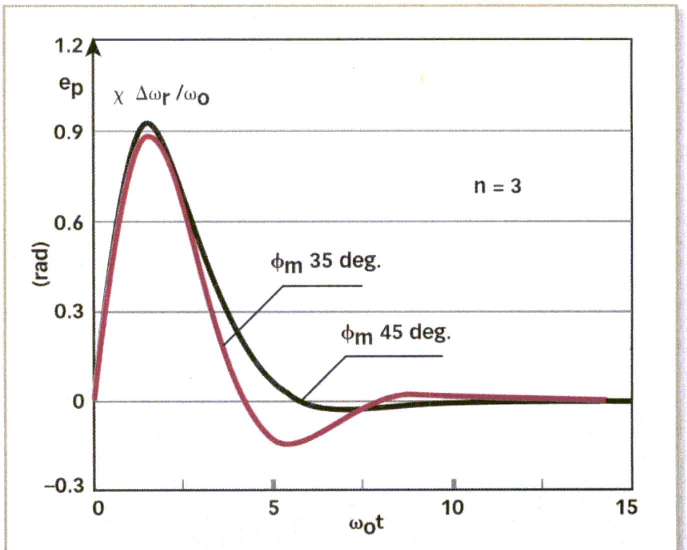
The condition n = 1 yields a third-order loop. For n > 1, all curves are close to each other, which means that for a particular phase margin, τ changes insignificantly with n. **Figure 9b** shows the dependence between τ and a. To compare frequency properties, **Fig. 10** shows the absolute value of the loop-transfer function |Fc(jΩ)| for two stability margins.

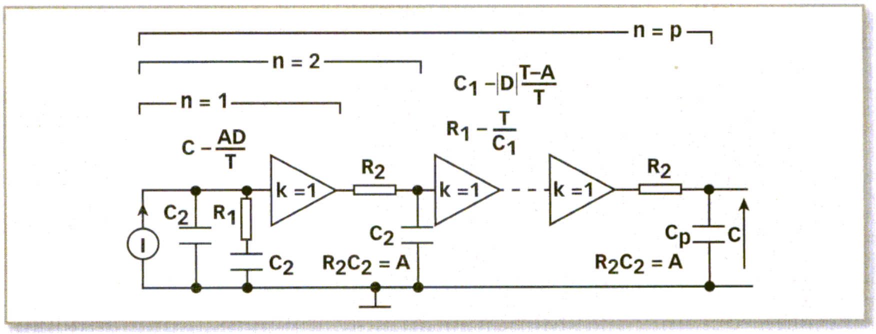
To illustrate the transient times, **Fig. 11** shows the phase-error response (normalized by $\Delta\omega_r / \Delta\omega_0$) for input-frequency step $\Delta\omega_r$ and n = 3. The curves for other n values differ insignificantly from those presented, and do not qualitatively change this description.



10. This shows the absolute value of the loop-frequency transfer functions depending on ϕ_m and n.

11. This shows phase-error time response for input-frequency step $\Delta\omega_r$ (input signal $\phi_r = \Delta\omega_r / s^2$).





12. This shows an example of realization p+1 order-loop filter F(s).

One should treat time responses with care, remembering the phase detector's limitation, which limits the entire linear model. As a first approximation, one can take transient time as approximately $12/\omega_0$ for a "typical" ϕ_m of approximately 45 deg. Frequency dependencies allow one to estimate, for instance, the x_d attenuation. For a better comparison among different order loops, **The table** shows the attenuations relative to a third-order loop (second-order filter, n = 1) in decibels, where n changes from 1 to 7, for two frequencies, and ϕ_m = 45 deg.

From Fig. 11 and the table, one can see that high-order filters (14) are more effective for high Ω. This is not practical since, in this frequency range, the VCO noise dominates the signal quality (independent of the filter in this range). Often the goal in loop design is to have high x_d attenuation for small Ω. For instance,

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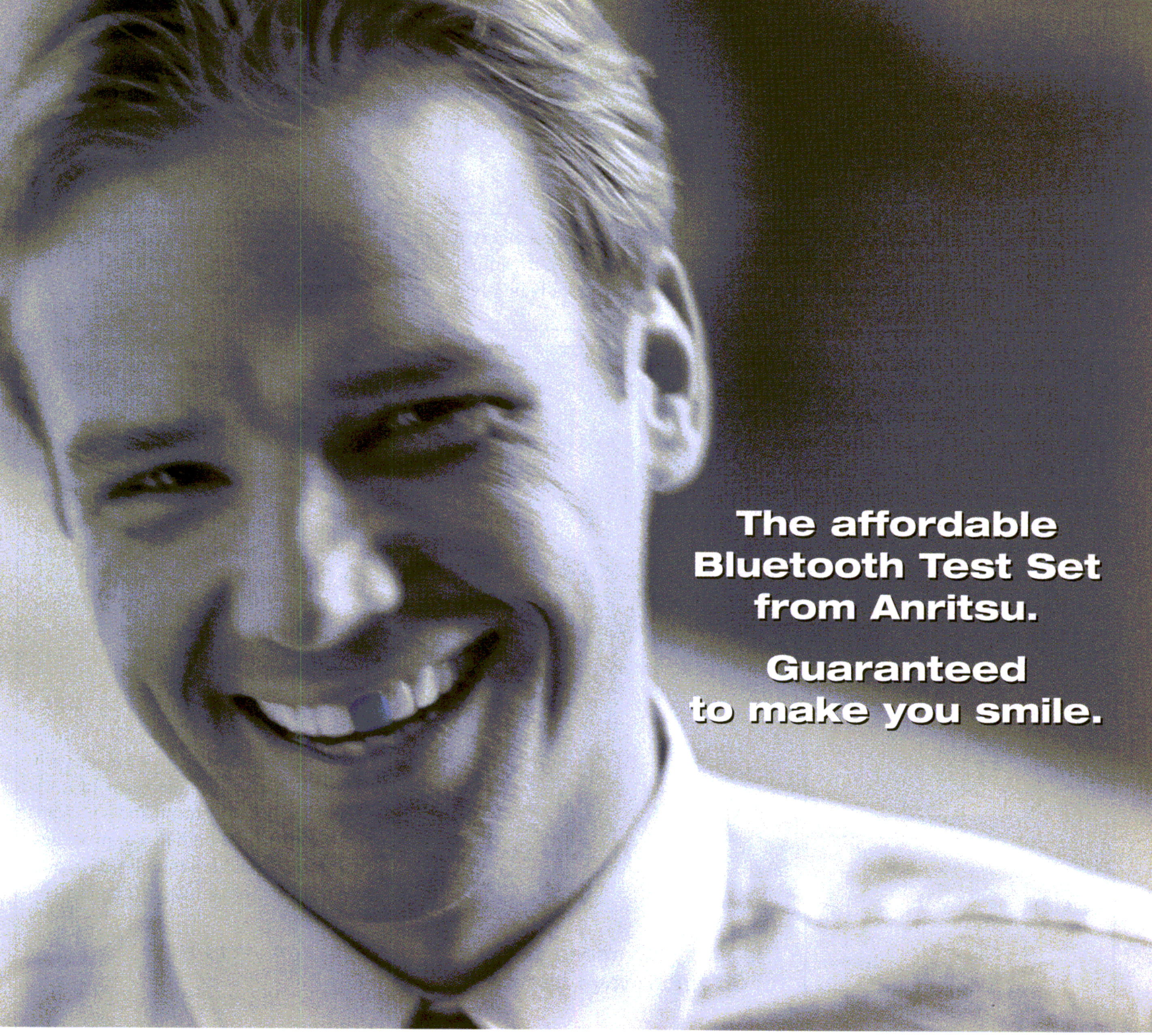

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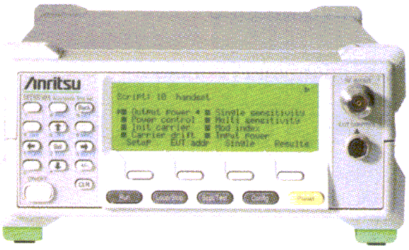

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Attenuations relative to a third-order loop (second-order filter, n=1) in decibels, where n changes from 1 to 7, for two frequencies, and $\phi_m = 45$ deg.

	n						
	1	2	3	4	5	6	7
25	0	7.5	11.1	12.5	12.7	12.1	11.1
50	0	13.3	22.2	28.0	32.8	35.7	37.5

Continued from page 82

if x_d is a spurious signal at $\Omega = 25$, one can find from the table that applying this filter with n > 3 is rather groundless and may even worsen the required parameters.

For particular values of ϕ_m and n, the calculations for these filters are simple. From Fig.9a, one can estimate τ (or calculate it numerically involving Eqs. 17a and 18) and determine a from Eq. 18. For $k = k_d k_{vco}$, a particular N and an assumed ω_0, one can obtain D, T, and A using Eq. 15a and b. One of the simplest possible active realizations, using ideal unity-gain buffers, is shown in **Fig.12**.

In this solution, one can assume that the output of the phase detector is modeled as a current source. Thus, it is possible to apply the active integrator as a first-order filter (n = 1) as shown in Fig. 8. This figure also shows the calculations for C, C1, and R1.

Finally, consider the case where n has a high value. First, after some algebraic manipulation of Eq. 18:

$$a \approx \frac{\tau}{n(1+\tau^2)} \qquad (19)$$

For example, taking $\tau = 2$, even with n up to 3, results in an error of only approximately 2 percent, and it is clearly seen that for a high n, a approaches 0. For the value shown in Eq. 17a, one can determine phase margin (n approaches ∞ as:

$$\varphi_m = arctg(\tau) - \frac{\tau}{1+\tau^2} \qquad (20)$$

This provides a curve that is very close to that shown in Fig. 9a for n > 1. In this case, "very close" means a negligible influence on loop performance, taking into account other practical disturbances.

Consider the following equation:

$$lim_{n\to\infty}\left(1+\frac{z}{n}\right)^n = e^z \qquad (21)$$

After substituting Eq. 19 into Eq. 14 with Eq. 15, one can write (n approaches ∞):

$$F(s) = \frac{1+Ts}{Ds}e^{-T_0 s}$$

$$where \quad T_0 = \frac{T}{1+\tau^2} \qquad (22)$$

This means that with the n approach-

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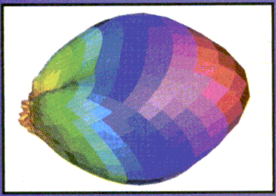

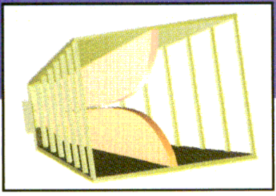

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es ∞ function, Eq. 14 reduces to a first-order filter with an ideal integrator (n = 0) and an additional delay line, delaying the loop low-frequency signal on T_0. For high values of n, Eqs. 15 and 19 yield $T_0 = nA$. This is not surprising, since the RC = A chain is a part of the realization from Fig. 12. For n approaching infinity, the transmittance Fc (jΩ) is:

$$F_c(j\Omega) = N$$

$$1 + j\tau\Omega\,/$$

$$-\sigma_{inf}\Omega^2 +$$

$$(j\tau\Omega + 1)e^{-jt_0\Omega}\ e^{-jt_0\Omega}$$

$$\text{where}$$

$$\sigma_{inf} = \sqrt{1+\tau^2}\ \text{ and}$$

$$t_0 = \frac{\tau}{1+\tau^2} \qquad (23)$$

This is presented in **Fig. 10.** All of these properties depend on the phase condition in Eq. 17. It determines whether t and a maintain a suitable stability level, and explains the deterioration of attenuation xd closer to the loop frequency for higher-order loop filters (Eq. 14). To achieve better performance closer to the loop frequency, additional notch filters can be used.[5, 6] But to attain the required stability margin, one must numerically adjust some component values. To decrease the active component noise in the output signal phase for frequencies higher than the loop frequency, ω_0, one can use the method described in reference 7. Here, the additional "attenuator" should be placed after the last active circuit. And, having some loop properties, the first filter part ought to be adequately corrected. MRF

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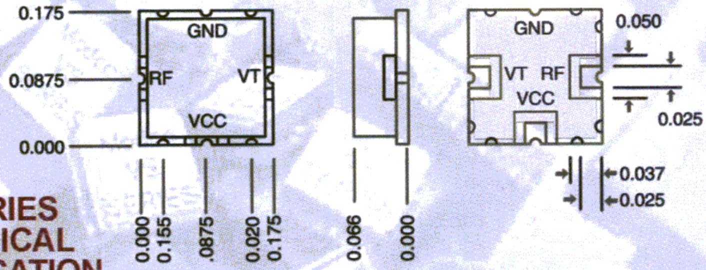

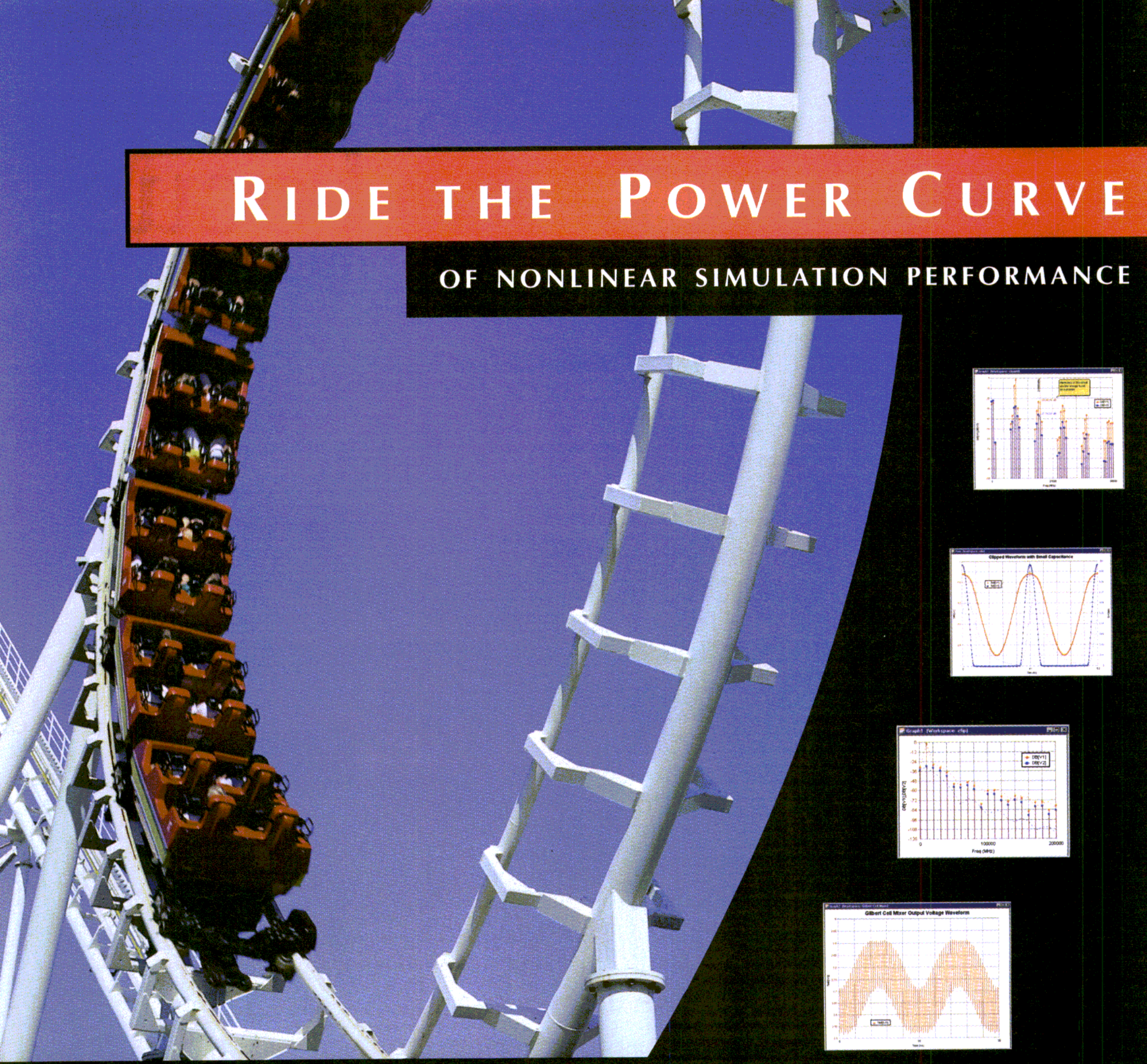
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Test RF Equipment With An Isolated T Capacitive Coupler

This versatile coupling device can be used to test various RF equipment without suspending the operation of the equipment or disturbing impedances.

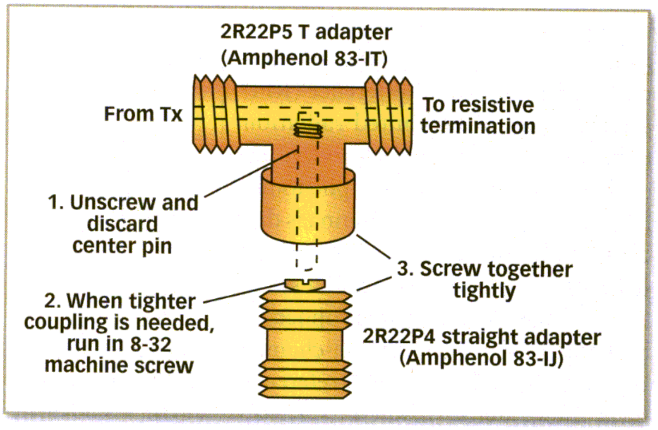
BOB SWINNEY
Applications Engineer, Andrew Corp., 2601 Telecom Parkway, Richardson, TX 75082; (972) 952-9719, FAX: (972) 952-0019, e-mail: bob.swinney@andrew.com

Whether the isolated T capacitive coupler (iso-T) is home-built or commercially manufactured, it is an essential device for investigating almost any two-way-radio interference (Fig. 1). This device allows engineers and technicians to measure test signals while the radio equipment is operating under normal conditions. Test personnel can use it to couple signals into and out of the system without upsetting impedance or damaging test equipment. This article describes the function of the iso-T, investigates some of its applications, and offers directions for constructing a homemade coupler.

Almost any measurable gap in the T can protect test equipment from transmitter (Tx) power. Normally, the device yields an unknown amount of isolation (capacitive coupling), but this is of little consequence since most measurements are made against relative values. Actual isolation varies directly with gap size and inversely with frequency. If desired, actual isolation can be measured with a receiver (Rx) [or spectrum analyzer] and signal generator. If needed, commercial T's are available with calibrated isolation. At 850 MHz, the capacitive reactance of a 0.1-pF gap is approximately 1.7 kΩ. This would not appreciably upset the nominal 50- or 70-Ω impedance of most RF equipment.

Test Applications

The iso-T, while ordinarily used in two-way-radio interference investigations, is also a handy device for checking the operation of bidirectional amplifiers (BDAs). These amplifiers carry critical communications into isolated loca-



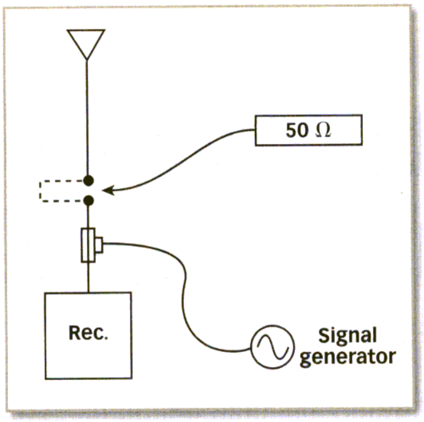
1. A capacitive coupler permits "closed" coupling without risk of damaging sensitive test equipment.

tions throughout the world. A long transportation tunnel, for example, may require communications access with the "outside world." Typically, tunnels using radiating cable have broadband distribution BDAs installed in a booster scheme that places one in the cable at each point where the signal has deteriorated by 20 dB. In cases where the downlink signal is partially disrupted at some point, an iso-T can be quickly installed at the output (downlink) port of a suspected BDA in the area. Service needs to be interrupted only as long as it takes to install the iso-T. The BDA "envelope" can then be examined to bracket the problem to a particular amplifier or section of radiating cable. In extreme cases, two iso-Ts can be installed, one on each port of the BDA, enabling low-level signal substitution testing without taking the BDA out of service. As with all signal-injection tests, there is the potential for intermodulation (IM) in the amplifier, so only very low levels of extra signal should be injected into the system.

The described tests may suggest techniques that can be employed in other communications systems. For example, two calibrated iso-Ts could be used to measure the gain and frequency response of a BDA as described before.

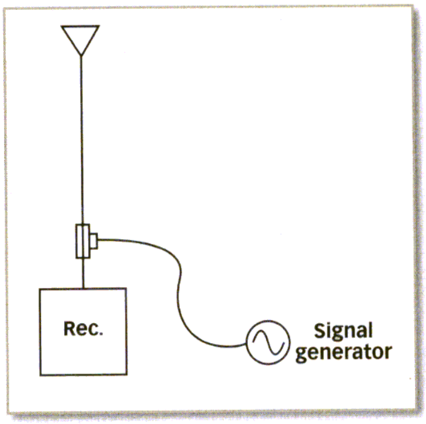
Rx Sensitivity Test

A radio Rx's sensitivity can be measured with an iso-T during the Rx's normal operation **(Fig. 2)**. The measurements can show actual usable sensitivity or effective sensitivity resulting from various degrading effects. Man-made noise and RF interference (RFI) are examples of unwanted radiation that can degrade Rx sensitivity. To evaluate the effects of these phenomena in a working Rx, the antenna is disconnected at the Rx input and replaced with a 50-Ω dummy load and a series iso-T. A signal generator is connected to the isolated port, and an on-channel signal is injected to obtain a reference level of Rx activity, such as 12-dB SINAD, or a specific limiter reading. The signal level is recorded. Next, the antenna is connected in place of the dummy load and the amount of signal required to produce the reference level is measured and recorded. The difference between the two signal generator settings represents the Rx desensitization caused by RF and/or noise coming from the antenna.



2. In this configuration, the iso-T can measure unwanted signals coming from the antenna that can degrade Rx sensitivity. Measurements are taken with either a dummy load or the antenna connected.

For example, with a dummy load on the iso-T's antenna port, assume it takes 11 μV (−86 dBm) to reach 12-dB SINAD. With the antenna in place of the dummy load, it takes 63 μV (−71 dBm) to obtain the same amount of Rx activity. The difference (15 dB) is the amount of Rx desensitization caused by interference coming from the antenna. Thus, the Rx's effective sensitivity is 15 dB less than its normal rated sensitivity. In this example, if the basic Rx sensitivity is 0.35 μV, it would have been degraded by 15 dB of "desense" to an effective sensitivity of 2 μV.



3. The iso-T can measure RFI or ambient noise, including inaudible noise desense forms. Measurements are taken with interference present and not present.

Ambient Noise Test

It is usually surprising to find several decibels of base-station-Rx desense from ambient noise at the site. This can be a real problem in Land Mobile Low Band and very-high-frequency (VHF) systems. Sometimes, Rxs in these bands show up to 20 dB of degradation caused by factors such as noisy power lines, switch yards, defective power-line insulators, etc. At ultra-high-frequency (UHF) frequencies, ambient noise generally accounts for much less Rx desense than in the lower bands.

A typical noisy location should cause no more than 1.5 dB of Rx desensitization in the UHF bands. If more than 2 or 3 dB of desense to UHF channels is measured, the Rx's performance is probably being degraded by RF signals rather than ambient noise. RFI is the main cause of degraded Rx performance at UHF and higher frequencies. As outlined previously, an effective Rx-sensitivity check will reveal Rx desense, regardless of the source. More tests are necessary to determine whether the source is RF or ambient noise, or perhaps both.

RFI Test

The iso-T can be used to measure RFI **(Fig. 3)**. The signal generator's output must be measured twice to acquire a reference level of Rx activity. The first measurement must be taken during a "quiet time" when the interference is not present. The second measurement must be taken when the interference is present. Listening to the channel may be helpful in making this determination, though some forms of interference, such as noise desense, are not audible. With noise desense, the Rx often seems to "go dead." An effective sensitivity test through the antenna will reveal this.

Continued on page 92

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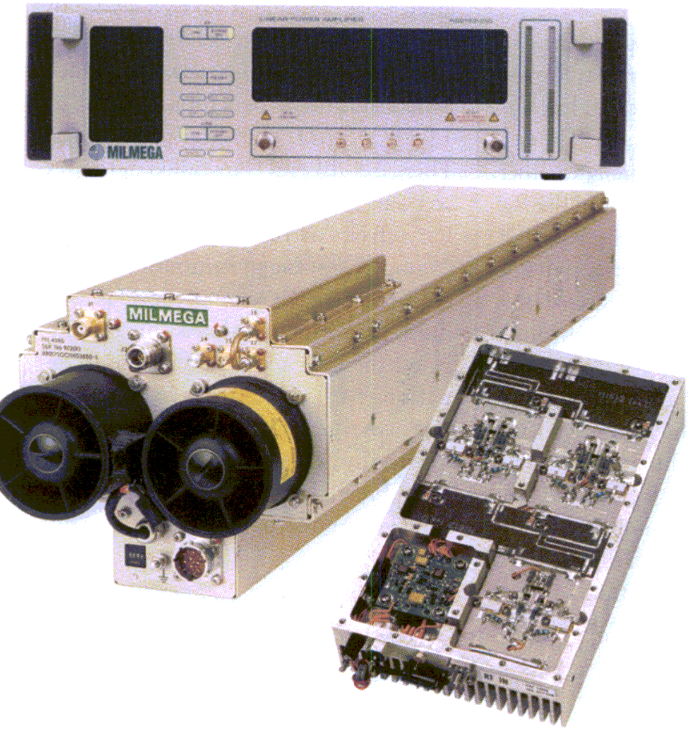

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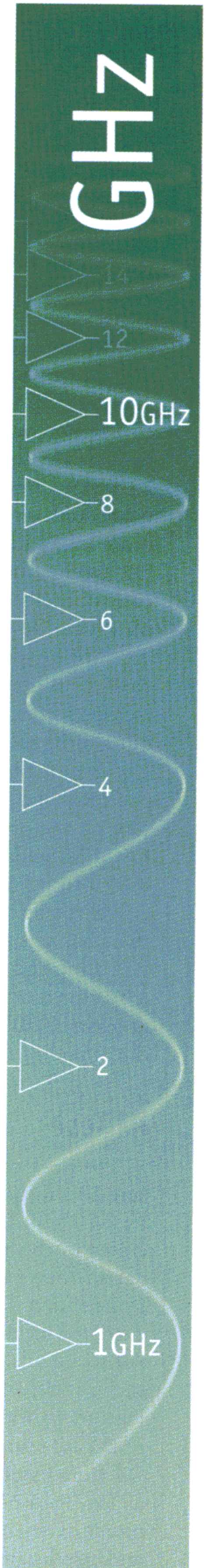

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With the iso-T connected through the antenna, all interference coming in on the antenna can be measured. One can experience RF and ambient noise desense at the same time. A quiet-time check and a check when interference is present are needed. The difference between these two readings represents the amount of degradation caused by interference.

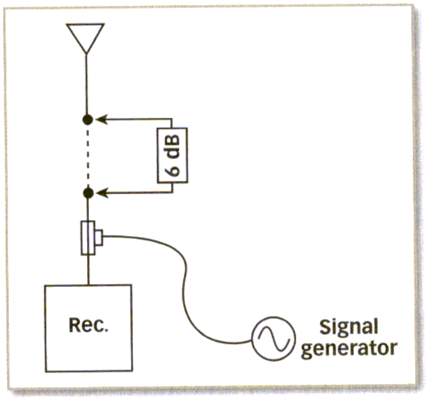
The RF could be from other nearby Txs, IM from two or more Txs, RF leaking into the Rx due to inadequate duplexers or combiners, or from loose or arcing components within the antenna under test. Oftentimes, offending Txs can be identified by observing desense when suspicious Txs are keyed and then unkeyed. Regardless of its source, two iso-T Rx measurements, one with and one without interference present, will provide an estimate of the size of an interference problem. Identifying the magnitude of the problem is the first step toward eliminating it. For example, if the Rx is getting "hit" with strong RF (10 dB greater than the carrier's power) two channels away in frequency, the Rx's front end may be sharpened with a bandpass or notch filter, providing at least 10-dB roll-off or rejection at the offending frequency.

IM Test

The iso-T can also be used to measure Rx desensitization effects caused by IM **(Fig. 4)**. IM is a form of RFI generated by the mix of two or more signals in a nonlinear device such as an Rx front end, a Tx final amplifier, or a corroded metallic joint behaving similar to a diode. Passive external mixes such as those occurring in a corroded joint are rather rare, and only two types of IM are usually present: Rx IM and IM from external active mixers such as Txs. The iso-T can measure the magnitude of desensitization caused by IM and help locate the source.

The most common type of IM is third-order Tx IM. Order indicates the numbered rank of harmonics participating in an IM mix. A typical third-order case results from a mix represented by 2A minus B, where A is the base station's Tx frequency and B is the frequency of another nearby Tx. This mix very likely occurs in the final amplifier of the Tx under test because the second harmonic (the 2A term) is very strong there. The resulting IM signal is quite capable of degrading the performance of nearby Rxs, including the one under test. IM interference always occurs in odd orders such as third, fifth, seventh, etc. This discussion focuses on Tx IM, which can occur in the final stages of power amplifiers (PAs). Very strong desense usually indicates a Tx mix that is close by and is generally on the same site.

IM from within the Rx is another distinct possibility **(Fig. 3)**. In fact, Rx IM is about as common as Tx IM, but it is a little more difficult to identify. The iso-T is a useful tool for determining whether IM is occurring externally or in the Rx under test. To find IM in the Rx, first a reference amount of Rx activity is obtained with the antenna connected normally and a test signal injected through the iso-T. Then, a small amount of attenuation or pad, approximately 6 dB, is connected in the receive coaxial cable coming from the antenna. The reference amount of Rx activity is re-established. If the second signal-generator reading is exactly 6 dB less than the first, it indicates that the IM mixing point is external to the Rx. If the amount of signal required to re-establish the reference level is substantially less than the pad, this indicates Rx IM. This is because each IM component is attenuated by 6 dB before mixing in the Rx. A difference of 18 dB would be a theoretical third-order response to three signals of equal amplitude mixing in the Rx. Reverting to a lower-value pad, approximately 3 dB, might be helpful in cases where the difference in signal-generator levels is hard to determine.



4. In this configuration, the iso-T can measure the magnitude of Rx desensitization caused by IM and help locate its source—either within the Rx or externally. Measurements are taken straight in from the antenna or through a pad.

For example, with an iso-T connected in line with the Rx coaxial cable and a signal generator feeding the isolated port, assume it takes a signal of −75 dBm to obtain a reference level of Rx activity. (Note that the reference level could be a benchmark, such as 12-dB SINAD, or a limiter reading.) Then, a 6-dB pad is installed in the Rx coaxial cable, and the reference level of Rx activity is re-established. In this example, assume the amount of signal required to reach reference level is −87 dBm. In as much as this is substantially less than the amount of in-line attenuation (pad), it indicates IM is occurring in the Rx. Had the IM been occurring externally, the signal-level difference would have been very nearly equal to the value of the pad.

Repeater Desensitization

Repeater desense caused by a station's Tx is easy to prove with an iso-T **(Fig. 5)**. The iso-T is placed in the input port of the Rx as shown, and two sensitivity measurements are made, one with the Tx unkeyed and the other with the Tx keyed. The difference between these two readings is the amount of Rx desense caused by the Tx. If duplexers or combiners are operating properly, there will be 0 dB of desense. Any degradation at all indicates inadequate RF isolation between Tx and Rx. The duplexer may be damaged, mistuned, or simply incapable of delivering enough isolation to protect the Rx. In a combiner, desense can be caused by any Tx in the system, including the one under test. Tx noise

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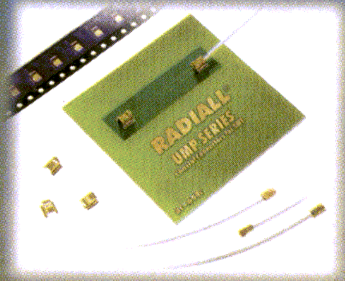

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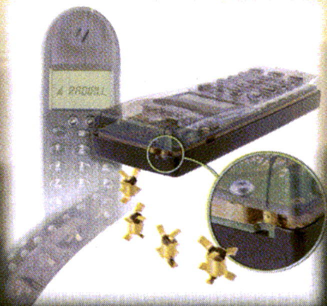

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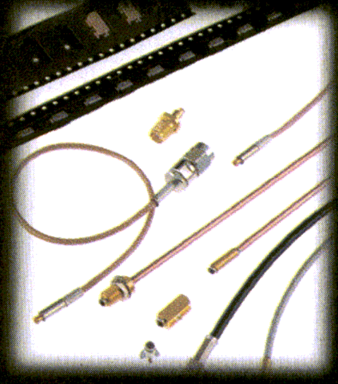

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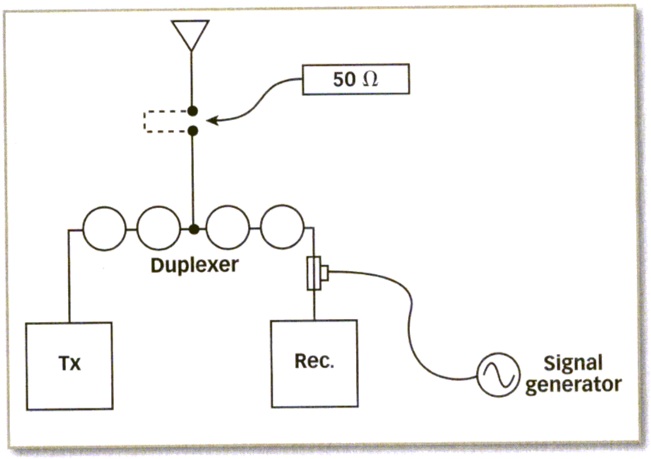
is the culprit and may be found by a process of elimination. Desense may be caused by arcing somewhere in the system. Noise desense from arcing can frequently be traced to faulty connections inside duplexers, combiners, and even antennas. If the coaxial cable and antenna are suspected, and if IM is not "inbound," the antenna system can be connected into the test in place of the dummy load.



5. In this configuration, an iso-T can measure repeater desense caused by the station's Tx. Measurements are taken with the Tx keyed and unkeyed.

A workable, home-built capacitive coupler can be improvised from commonly available coaxial connectors. The male center pin of the common UHF series T adapter threads into a tube, which serves as the two female contacts. The pin should be unscrewed and discarded. This leaves the tube loose. A drop of epoxy will hold it in place. When a straight adapter is screwed into the modified T adapter, there is no direct contact between the center conductor of the T adapter and the center conductor of the straight adapter. However, there is capacitive coupling between them. The T adapter is installed in-line between Tx and RF wattmeter. Test equipment is energized from the straight adapter. If loss is too great, capacity (and coupling) can be increased by threading a machine screw into the unexposed end of the straight adapter. Coarse adjustment can be achieved by running the screw in and out. However, direct contact between the screw head and the "through" path must be avoided.

All engineers should have an iso-T in their toolboxes. It maintains proper termination while isolating instruments from the Tx and outside RF signals and noise. Whether working at "low band" or 1900 MHz, the iso-T is a valuable assistant to measure and identify RFI. MRF

Emulator Mimics Mobile Communication Channels

Continued from page 66

Gaussian, or Ricean. The standard deviation for phase can be adjusted from 0 to 180 deg. Calculation of all emulation parameters is performed in real time, so that it is possible to modify any parameter during an emulation. The channel emulation simulation also allows operators to save system-level configurations in different files, making it possible to reproduce complex signal environments, such as combinations of urban and forest areas.

The channel emulator system has many possibilities and capabilities. The emulator can be used alone to measure and study the response of a channel, while the multipath unit can be used to create a delay profile that is then measured with a network analyzer. Examples of this latter application are shown in **Figs. 6 and 7**. Figure 7 shows the frequency response of a channel measured at IF. The test results show one dominant signal ray and five multipath components. The channel emulator system's fading depth capability of more than 40 dB can be seen from these measurements.

The channel emulator can also be used for performing closed-loop emulations of communications channels for bit-error-rate (BER) measurements. It is possible to connect a modulator and a demodulator through the system and measure the BER and I/Q diagram of a received signal. This test evaluates the effect of a digitally modulated channel with very high accuracy and in a very short period of time. With the channel emulator, it is possible to create a channel and measure the behavior of different modulation schemes under a variety of conditions. Measurements of this kind[6] have been performed with binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), and CP-FSK formats at different data rates.

The system developed by the authors represents a complete laboratory for the study of mobile radio channels under multipath conditions. The low-cost system was developed with available hardware and specialized control software, enabling full control of all propagation parameters and thorough investigation of communications-channel characteristics. MRF

ACKNOWLEDGEMENTS

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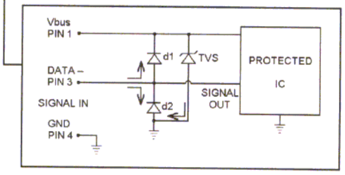

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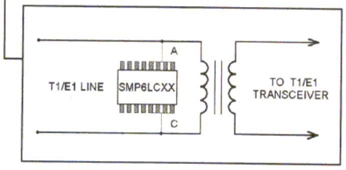

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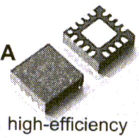

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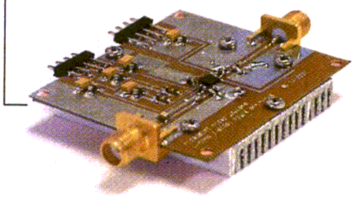

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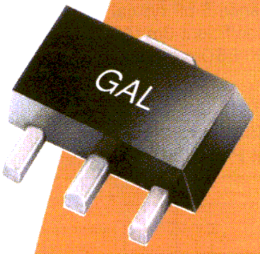

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GAL-2	DC-8000	16.2	14.8	±0.7	12.9	4.6	27	101	40	3.5	.99
GAL-33	DC-4000	19.3	17.5	±0.9	13.4	3.9	28	110	40	4.3	.99
GAL-3	DC-3000	22.4	19.1	±1.7	12.5	3.5	25	127	35	3.3	.99
GAL-6	DC-4000	12.2	11.8	±0.3	18.2	4.5	36	93	70	5.2	1.49
GAL-4	DC-4000	14.4	13.5	±0.5	17.5	4.0	34	93	65	4.6	1.49
GAL-51	DC-4000	18.1	16.1	±1.0	18.0	3.5	35	78	65	4.5	1.49
GAL-5	DC-4000	20.6	17.5	±1.6	18.0	3.5	35	103	65	4.4	1.49

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MEMS Technology Moves Increasingly Toward Microwave Applications

MEMS offer reduced cost, size, and power-consumption advantages to RF and microwave hardware designers.

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Microelectromechanical systems (MEMS) represent an exciting technology based on the same fabricating processes used to make integrated circuits (ICs). Current and future RF, microwave, and millimeter-wave systems will require more flexible and sophisticated devices, but with very low weight, small volume, and low power consumption. Examples include wireless communications equipment such as mobile phones for messaging, wireless Internet accessing for e-commerce, as well as wireless data links such as the Global Positioning System (GPS) and Bluetooth. A technology that can contribute to these efforts is MEMS, a planar fabrication process compatible with existing integrated-circuit (IC) and monolithic-microwave-integrated-circuit (MMIC) processes. In the 21st century, the state of the art in multichip modules (MCMs) for RF and microwave systems will be the development of an advanced technology that can integrate silicon/germanium (SiGe)-based active devices, MEMS devices, and micromachined components into one wafer.[1]

A MEMS is a miniature device or an array of devices combining electrical and mechanical components and fabricated with IC batch-processing techniques. It can range in size from micrometers to millimeters. MEMS fabrication techniques employ conventional IC fabrication processes to produce three-dimensional (3D) mechanical structures. Accordingly, there are several MEMS fabrication techniques currently in widespread application, including bulk micromachining, surface micromachining, fusion bonding, and a process known as LIGA, which is a German acronym that means Roentgen-LIthographie, Galvanik, Abformung.

The most important technique is surface micromachining, which consists of the deposition and lithographic patterning of various thin films, usually on a Si substrate. MEMS devices for RF and microwave applications can provide the advantages of fast actuation, low losses, and high quality factors (Qs), which is an attractive option.[2] To some extent, MEMS represents the new revolution in microelectronics.[3] An alternative to Si as a substrate material came about with the intent of applying surface-micromachining techniques to incorporate microwave MEM devices in MMICs.

Most RF MEMS are fabricated using gallium-arsenide (GaAs), ceramic, high-resistivity Si, or other RF-compatible materials. Employing flip-chip assembly and Si-removal techniques,[4] it is possible for a MEMS device to be integrated on any RF-compatible substrate without Si semiconductor effects, to fabricate complex MEMS cost-effectively for a new generation of RF MEMS with superior functionality.

From an RF and microwave viewpoint, current MEMS technology focuses on switches, filters, inductors, variable capacitors, and phase shifters for wireless-communication applications.[5] In the future, integrated MEMS will become a reality.

MEMS Fabrication

In the MEMS fabrication process, permitting one or more of the ("release") films to be free standing over a selected part of the substrate, including polysilicon, enables the film to undergo the mechanical motion or actuation characteristic of all MEMS. This is performed by depositing a "sacrificial" film (or films) below the released one(s), which is removed in the last step of the process by selective etchants. Materials for the release and sacrificial layers include metals [gold (Au), aluminum (Al), etc.], ceramics [Si dioxide (SiO_2) and Si nitride (Si_3N_4)], and plastics [photoresist, polymethyl methacrylate (PMMA), etc.], depending on the details of the MEMS process and other materials in the thin-film stack. The release and sacrificial layers can be deposited through evaporation, sputtering, electrodeposition, or other methods. Currently, the substrate materials used for MEMS fabrication include quartz ($\epsilon_r = 3.8$); semi-insulating GaAs, high-resistive Si substrate ($\epsilon_r = 11.9$); alumina; strontium titanate oxide (SrTiO3); SiO2; and more.

The next important achievement in the development of surface-micromachining technology was its exploitation of structural polysilicon and sacrificial SiO_2 to fabricate free-moving mechanical gears, springs, and sliding structures. Since systems applications require that sensors and actuators interface with electronic circuitry, attention turned to the simultaneous fabrication of micromechanical devices with ICs.

Already well-known, good packaging practice is essential for the successful performance of conventional RF and microwave components. The case for MEMS is no different. Indeed, in addition to ensuring the absence of unwanted resonance and electromagnetic interference (EMI) and coupling, MEMS packaging techniques aim at preventing moisture and particulates, which may impair the movement of freestanding MEMS structures, and the various types of energy losses (e.g., acoustic and thermal).

RF and microwave components benefit greatly from MEMS technology due to the low-loss characteristics of low-resistance metal contacts and the elimination of dielectric losses in planar waveguides. Due to the miniaturization feature, many different components can be integrated on a single chip to achieve more functionality without extra connector losses or impedance-mismatch losses. The movable feature of MEMS devices enables dynamic adjustment of the component value.

> [The advantage of RF and microwave MEMS switches over traditional semiconductor devices is their low series resistance.]

Switches/Capacitors

Perhaps the most prolific RF and microwave MEMS device is the switch. Promising realizations of the switch have been demonstrated as cantilevers, membranes, shape-memory alloy, and multipole/multi-throw devices that deform when subjected to electrostatic actuation forces.[6] The actuation mechanisms include electrostatic, piezoelectric, thermal, magnetic, and bimetallic (shape-memory alloy). While various actuation mechanisms are under investigation for MEMS device applications, electrostatic actuation is the most mature, perhaps due to the fact that surface micromachining, the most common technology used to produce electrostatically-based actuators, is compatible with IC fabrication processes.

As a basic device, the MEMS switch has been used to form other components, such as tunable filters, switched attenuators, reconfigurable antenna elements, phase shifters, analog single multiplexers, and other circuits or systems.[7-9]

Si micromachining has been used effectively for RF and microwave switches with an insertion loss of less than 1 dB over frequencies ranging from 100 MHz to 30 GHz.[10] It is compatible with Si processing and is orders of magnitude lower in cost than current GaAs technology. The advantages of the micromachining switch structure are that it needs very low power and has a long lifetime. The switches can provide speeds of 0.1 to 1.0 µs with a DC voltage of less than +3 VDC. The advantages of integrating these devices into existing passive circuitry on ceramic or glass substrates are that one can build very- low-loss interconnects with low parasitic parameters.

Current RF and microwave MEMS switches have been fabricated in series and shunt configurations. In the series configuration with the MEMS switch actuated (i.e., the top electrode pulled down), the signal path is completed, whereas in the shunt configuration, the signal path is shorted to ground with the switch actuated.[11] The typical shunt-capacitive MEMS switch consists of a thin metal membrane "bridge" suspended over the center conductor of a coplanar waveguide (CPW) and fixed at both ends to the ground conductors of the CPW. Metal membrane switches show good insertion loss, reasonable switching voltages, fast on/off speeds, and excellent linearity.[12] Using this approach, a novel tunable cross-switch is fabricated. The tuned cross-switch has an on-state capacitance of 0.05 pF and an off-state capacitance of 0.8 pF. The reflection coefficient in the on-state is less than −20 dB over 22 to 38 GHz with an insertion loss of 0.6 dB. The isolation of the cross switch is greater than 40 dB from 20 to 40 GHz.

Continued on page 100

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Continued from page 98

The pull-down voltage for the membranes is +15 to +20 VDC.[13]

The advantage of RF and microwave MEMS switches over traditional semiconductor devices, such as FETs or PIN diodes, is their extremely low series resistance and low drive-power requirements, resulting in extremely low loss. In addition, RF and microwave MEMS switches without a semiconductor-junction effect exhibit negligible intermodulation distortion (IMD) in wireless-communication applications.

Various RF and microwave MEMS switches used in every application have been reported. Most of them consist of sputtered or evaporated thin-metal films and Si_3N_4 or SiO_2 using rotary,[14] cantilever,[15,16] or membrane[17-19] topologies. Usually, the switches are electrostatic in nature and are commonly driven by bias voltages ranging from +30 to +50 VDC. To obtain low insertion loss and low actuation voltage, various transmission-line structures, such as hinge and movable-plate constructed from electroplated Au or Cu, are being investigated. To obtain high on/off isolation, strontium titanate oxide ($SrTi_4O_2$) with a high dielectric constant is used. A recently fabricated switch with insertion loss as low as 0.08 dB at 10 GHz and isolation up to 42 dB at 5 GHz, has been realized.[20] Even better performance of RF and microwave MEMS switches with actuation voltages as low as +9 VDC[21] and isolation over 45 dB have also been demonstrated.[22]

Recently, for applications in 3D MMIC transmitter (Tx)/receiver (Rx) modules, an interlayer RF and microwave MEMS capacitive-switch structure sandwiched between two polyimide layers and two ground planes was proposed. The switch structure and the CPW in the switch region were optimized for low insertion loss in the on-state and high return loss and high isolation in the off-state.[23]

There are two forms of variable capacitors—parallel plate and interdigital. In the parallel-plate approach, the top plate is suspended a certain distance from the bottom plate by suspension springs, and this distance is made to vary in response to the electrostatic force between the plates induced by an applied voltage. The parallel plate type has a measured nominal capacitance of 2.05 pF, a Q of 20 at 1 GHz, achieves a tuning range of 1.5:1, a tuning-voltage range of 0 to +4 VDC, and a self-resonant frequency of greater than 5 GHz. In the interdigitated approach, the effective area of the capacitor is varied by changing the degree of engagement of the fingers of comb-like plates. Typical performance includes a Q of 34 for 5.19 pF at 500 MHz, a tuning range of 200 percent, a tuning-voltage range of +2 to +14 VDC, and a self-resonant frequency of 5.0 GHz for 5.19 pF. The reported linearity, as measured by the third-order IM product, is greater than +50 dBm.

A variable capacitor fabricated in a Multiuser MEMS Processes (MUMPs) or surface polysilicon micromachining process, has a nominal capacitance of 1.4 pF and a Q of 23 at 1 GHz and 14 at 12 GHz. As the bias voltage is swept from 0 to +5 VDC, the capacitance is tunable from 1.4 to 1.9 pF. It is used for a 2.4-GHz complementary-metal-oxide-semiconductor (CMOS) voltage-controlled oscillator (VCO) as the frequency-tuning element. The VCO achieves a phase noise of −122 dBc/Hz at 1-MHz offset from the carrier and has a tuning range of 3.4 percent.[24] An excellent example is the use of MEMS switches in digital capacitor banks or arrays. In addition, different fixed-value thin-film capacitors connected to external circuits through MEMS switches make up a capacitance bank, so that the total capacitance can be changed in a digitally controlled manner.[25]

A novel surface-micromachined Micro-Elevator by Self-Assembly (MESA) technique is used to build suspended inductors and variable capacitors. The MESA technology is unique since it offers a new approach to achieve large out-of-plane structures without using thick sacrificial layers or LIGA process.[26] The inductance is measured to be 24 nH and the capacitance varied from 20 to 500 pF.

In the design of RF and microwave MEMS switches, two important factors must be considered—electrical design parameters including transition time, switching speed, switching transients, RF power handling, intercept point, RF insertion loss, and isolation. The second factor is RF characteristics including lowest possible insertion loss, highest possible isolation, highest possible switching frequency, and lowest possible actuation voltage. The insertion loss is affected by mismatch loss where the characteristic impedance is different from 50 Ω.[27]

Phase Shifting

Traditional electronic phase shifters are generally built on GaAs and use metal-semiconductor field-effect transistors (MESFETs) or pseudomorphic high-electron-mobility transistors (pHEMTs) as switches. These devices switch between different line lengths or switch between different low and highpass filters to achieve the desired phase shift. However, these are comparatively lossy switches, with the average loss at Ka-band being approximately 6.5 dB for a 4-b phase shifter that uses the best pHEMT switches. Ka-band 3- and 4-b phase shifters have been built using a resonant-switched transmission-line microstrip topology. To shift the phase, two RF and microwave MEMS capacitive switches were used to form two quarter-wave transformations for the different path delays. The results show a 0-to-337.5-deg. phase shift with 22.5-deg. steps for the 4-b phase shifter, and 0- to-315-deg. phase shift with 45-deg. steps for the 3-b phase shifter. The average insertion loss is 2.25 dB and 1.4 dB[28] for the 4-b phase shifter and 1.7 dB for the 3-b phase shifter.[29]

The compatibility of membrane-switch construction with Si-CMOS processing makes it possible to integrate switches with other passive RF and microwave devices. Using this switch, a 4-b time-delay phase shifter where various transmission-line lengths are interconnected, has been investigat-

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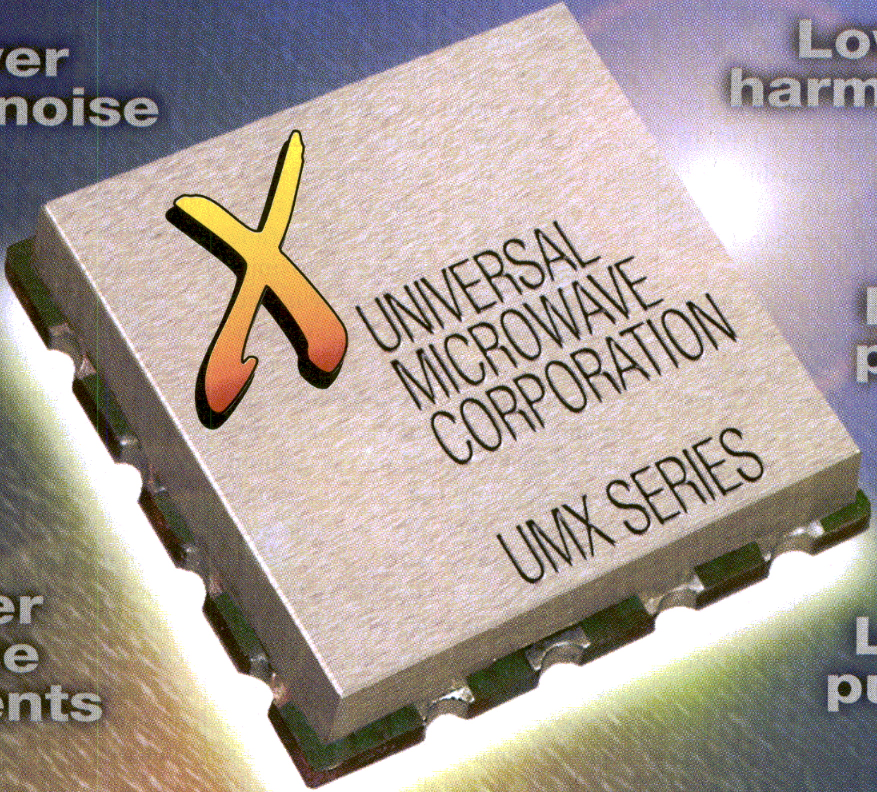
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ed.[30] Measured results show that any differential phase value from 0 to 360 deg. can be achieved in 22.5-deg. increments by tuning the switch positions. A large, low-cost phased array was built using the integration properties of the membrane switch with other devices. A distributed 1-b phase shifter based on RF and microwave MEMS capacitors with the lowest insertion loss at K/Ka-band has been reported.[31] The phase shifter demonstrated a phase shift of 180 deg. with an insertion loss of 1.17 dB at 35 GHz, a 270-deg. phase shift with an insertion loss of 1.69 dB at 35 GHz, and a return loss of better than 11 dB over the 0-to-35-GHz band.

A new type of tunable filter using micromachined cantilever-type variable capacitors is in development. The capacitors are used as a part of the resonators in bandpass filters for frequency tuning. The bandpass filters operate at Ka-band with a tuning range of 1.1 GHz for a two-pole lumped-element filter, and 0.8 GHz for a two-pole resonator filter.[32] These experimental results show that micromachined tunable filters are candidates in highly integrated Rx applications.

Resonators And Lines

The performance levels typical of macroscopic waveguide resonators can be approached at the microscopic planar level by exploiting micromachining techniques. In one particular demonstration, an unloaded Q of 506 for a cavity with dimensions 16.00 × 32.00 × 0.465 mm^3 was obtained. This was only 3.8 percent lower than the unloaded Q obtained from a rectangular cavity metal of identical dimensions.

The performance of bulky mechanical resonators, particularly the fact that they are capable of exhibiting Q in the 10,000 to 25,000 range, is well-known. The maximum resonant frequency reported for these resonators is less than 200 MHz. A film-bulk-acoustic-resonator (FBAR) device consists of a layer of piezoelectric material [for example, aluminum nitride (AlN)] disposed between top and bottom metal electrodes. The typical Q and resonance frequency are more than 1000 and between 1.5 and 7.5 GHz, respectively.

The limitations of transmission lines include frequency dispersion, insertion loss, and the properties of the substrate. RF and microwave MEMS technology has been successfully exploited to diminish the influence of the substrate in four types of transmission lines: the membrane-supported microstrip, coplanar microshield, top-side-etch CPW, and micromachined waveguide. In the membrane-supported microstrip, the transmission line is defined on a thin membrane with dielectric constant close to unity by bulk-etching the substrate underneath the trace through backside processing. A drawback is that it possesses no intrinsic ground plane. The coplanar microshield overcomes this limitation by including the ground planes defining the ground-signal-ground structure. The top-side-etch CPW does away with the potential complications of backside-etching of the membrane and microshield lines and, instead, relies on opening etch windows through the top passivation layer to create a pit underneath the line. The micromachined waveguide is a technique where micromachining and wafer-bonding techniques attempt to overcome the lower-dimension bound of conventional machining techniques.[33]

MEMS Modeling

Since MEMS technology is a combination of micromachining and IC technology, its computer-aided-design (CAD) packages include the following functions:

- The layout and processing for the MEMS device itself.
- The circuitry for the surrounding system and its interaction with the MEMS components.
- The package that will fit the MEMS component or subsystem into an application.

CAD for MEMS, therefore, uses tools from mechanical and IC design. Some specific CAD tools for MEMS based on IC CAD tools have been developed in the past. The first MEMS design system MEM CAD was built in the Senturia Lab at the Massachusetts Institute of Technology (MIT).[34] Others, such as those reported by S.B. Crary,[35] include design rules and anisotropic etching verification, parameter extraction, system-level simulation, and schematic-driven layout generation that enable MEMS designs to be ready to go to fab.[36]

Some MEMS CAD tools address specific demands, such as 3D analysis (OYSTER[37]) MEMCAD, and etching (ASEP[38]).

In the design of MEMS-based RF and microwave switches, full-wave EM simulators, such as Agilent's Momentum, are used[39,40] to obtain parameter extraction from S-parameter measurements and modeling.[41] Numerical simulation for high-frequency behavior of MEMS switches using Method-of-Lines (MoL)[42] and Transmission-Line-Method (TLM) methods shows very good agreement with measured results, so that the element extraction of accurate equivalent circuits using time-domain analysis can be realized.[43] The model parameters are obtained to fit the S-parameters simulated from full-wave EM simulation in Ansoft's HFSS.[44]

The current CAD environment provides a complete design flow for system designers. However, the integration of tools used by device designers is still being investigated.

RF and microwave MEMS techniques have been used to create smart or tunable antennas for military aircraft. With evolving development trends, RF and microwave MEMS will supplant discrete inductors, capacitors, ceramic filters, and even transistor switches in navigation radios, airborne-communications equipment, and personal-communications devices. They can be integrated with amplifiers, VCOs, phase-locked loops (PLLs), and other ICs.

Although the superiority of MEMS has been demonstrated in many RF and

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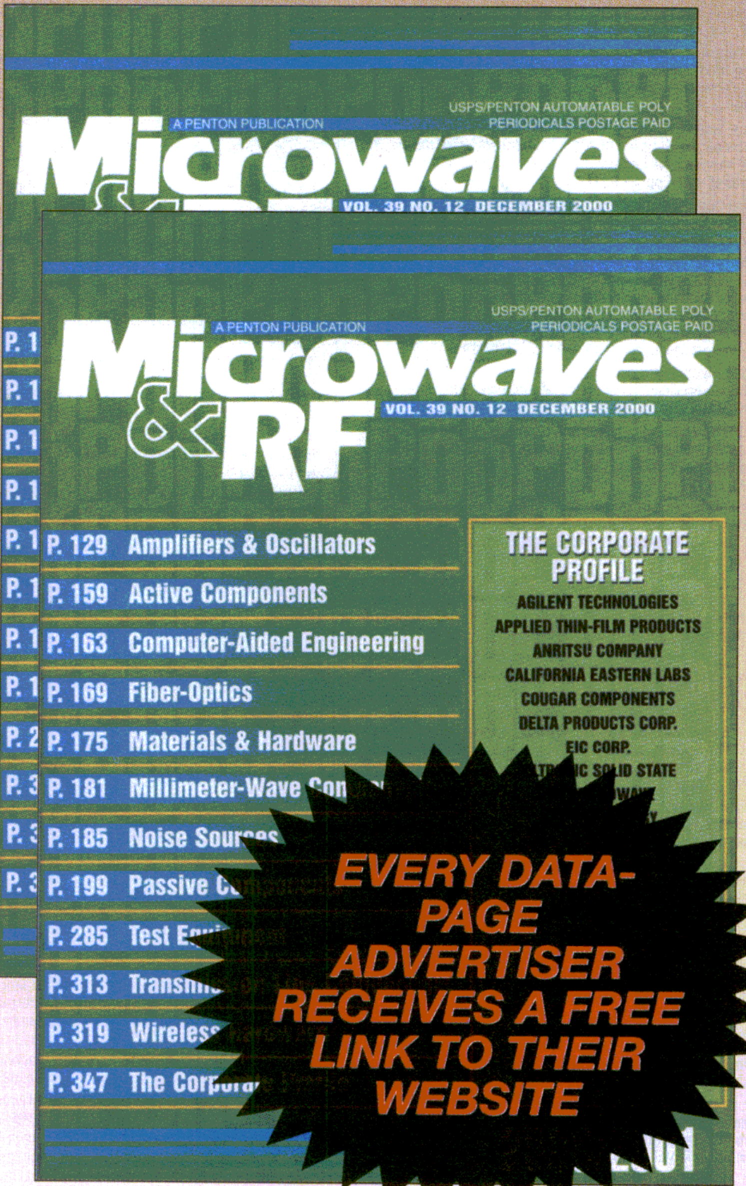

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microwave applications, much work remains through the further study of switch layout as well as materials packaging and processing.[45] MRF

ACKNOWLEDGEMENT

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Harmonic Tuners Support Accurate Load-Pull Testing

Harmonic tuners can be integrated into a very compact test system for accurate load-pull characterization of high-power microwave transistors.

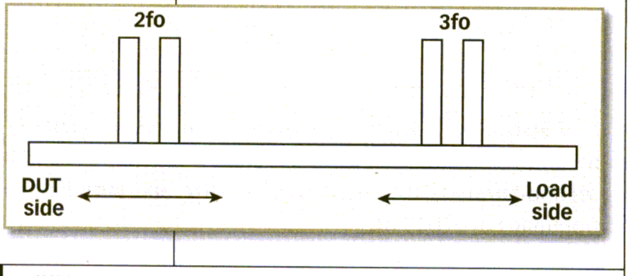
CHRISTOS TSIRONIS, ALGIS JURENAS, AND CHRIS (WEI) LIU

Focus Microwaves, Inc., Ville St. Laurent, Quebec, Canada; (514) 335-6227, FAX: (514) 335-6287, e-mail: christos@focus-microwaves.com, Internet: www.focus-microwaves.com

Load-pull testing is an important tool in the characterization of high-power, high-frequency transistors. By using load-pull tuners in an integrated test system to precisely control the impedance of a microwave transistor, it is possible to characterize the device's strongly nonlinear behavior, thus generating hot current-voltage (I-V) curves, plots of saturated power, and plots of load-pull contours. The availability of harmonic tuners with high-resolution tuning adds a new dimension to load-pull testing, allowing characterization to be performed under controlled conditions of second- and third-order harmonic impedances.

The highly reflective frequency-selective harmonic impedance tuners provide fine tuning accuracy between 0.2 and 0.7 deg. over a full 0-to-360-deg. interpolated tuning range. The tuning precision is obtained through precise alignment supported by calibration and nonlinear interpolation algorithms that enable reproduction of arbitrary impedances with accuracy typically exceeding −50 dB at the edge of the Smith chart.

Increasing demand for wireless services has made the job of the amplifier designer more challenging, requiring designs with improved linearity and power-added-efficiency (PAE) performance. The need for fast design turnaround has brought harmonic tuning, considered an exotic technique until recently, to the foreground. Among the three device-characterization techniques typically used,[1] including active harmonic load-pull testing, passive tuning using triplexers, and passive tuning using frequency-selective harmonic tuners, the last method became the most popular due to the compact nature of the setup, the affordability of the hardware, the ease of operation, and the wide frequency range. The method also delivers very useful, highly accurate data that can be incorporated into most nonlinear device characterization and amplifier-design schemes.



1. The principle of a harmonic load-pull tuner is based on sliding resonator circuits connected in parallel to a low-loss transmission line.

Continued from page 107

Passive tuning through frequency-selective harmonic tuners is a technique that uses patented harmonic load-pull tuners developed by Focus Microwaves (Ville St. Laurent, Quebec, Canada). These tuners can be used as part of a dedicated test system or as an extension to existing load-pull systems. The harmonic tuners are based on the principle of sliding resonator circuits connected in parallel to a low-loss transmission line. Tuners usually employ two sets of two resonators to cover the second- and third-harmonic frequencies—$2f_0$ and $3f_0$ **(Fig. 1)**. The use of two resonators per harmonic frequency is necessary to provide compensation of the residual reflection at the fundamental frequency that would result from a single harmonic resonator.

2. Harmonic tuners are part of this compact harmonic load-pull measurement system which also employs a VNA and DC power supplies.

These harmonic tuners **(Fig. 2)** generate a very high reflection factor between 0.95 and 0.99 at both harmonic frequencies over an adjustable phase range of 360 deg. and are connected directly to the device under test (DUT). Their insertion loss at the fundamental frequency is very low (0.05 to 0.10 dB) and does not noticeably reduce the minimum reflection factor of the fundamental tuners. This performance is typical to 2 GHz, beyond which the transmission-line insertion loss reduces the reflection factor to values of approximately 0.92 to 0.95. Although the harmonic tuners do not permit changing the amplitude of the reflection factor, all experimental and theoretical evidence to date has shown that the variation of the reflection factor amplitude is not required to fully characterize a power transistor. **Figure 3** shows the typical frequency response of the harmonic tuners.

The harmonic tuners are calibrated on an automatic vector network analyzer (VNA) at the fundamental and both harmonic frequencies simultaneously. For each adjustment position of the first set of resonators, the user-defined impedances of the alternate harmonic are calibrated. This information is then used to develop second-order polynomial algorithms that interpolate between calibration points with very high accuracy. These algorithms can provide performance with phase errors on the order of only 0.1 to 0.3 deg. and amplitude errors between −40 and −60 dB **(Fig. 5)**. Additional algorithms are used with the harmonic tuners to compute and display the impedances associated with any arbitrary position of the sets of resonators.

The step size of the tuning mechanism (i.e., a stepper motor or other device) dictates the limit of the harmonic load-pull tuner's tuning resolution, typically 12 to 25 μm. This corresponds to minimum phase steps of 0.026 to 0.052 deg. at 900 MHz. The phase resolution decreases in inverse proportion to frequency, but can be

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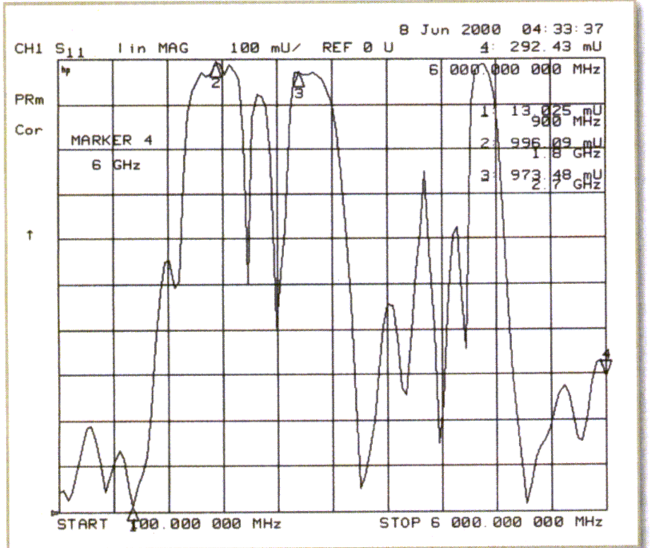
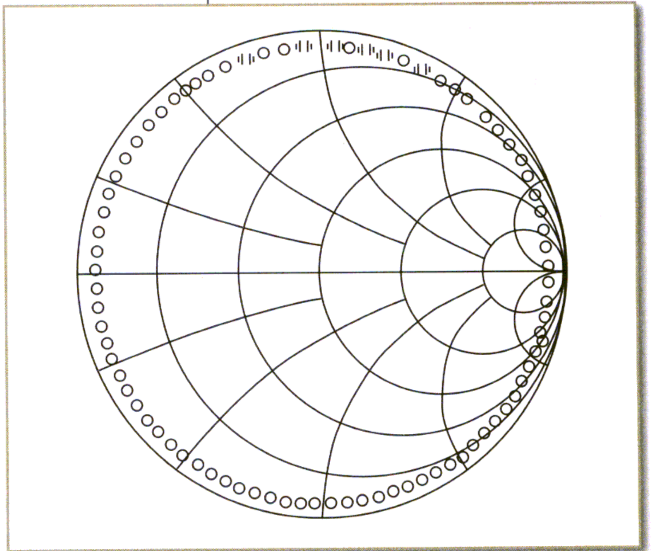


3. These plots show the typical frequency response of harmonic tuners tuned for a fundamental frequency of 900 MHz, second-harmonic frequency of 1800 MHz, and third-harmonic frequency of 2700 MHz.



4. This plot above shows a third-harmonic calibration pattern that is for harmonic tuners which operate at 1.9 GHz. The second-harmonic pattern features an even higher reflection factor.

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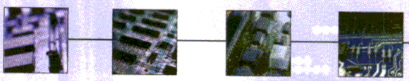

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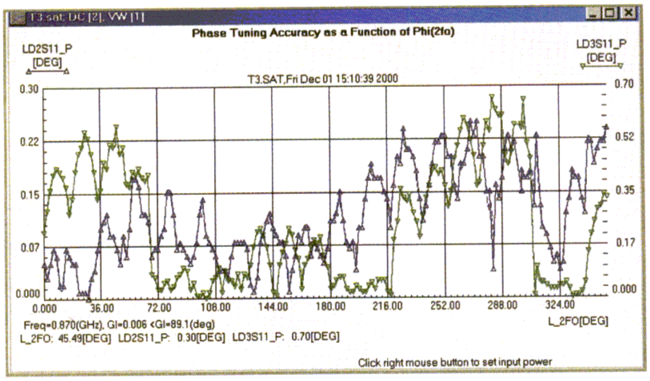


5. The tuning accuracy of a harmonic tuner operating at 870 MHz is shown for second-harmonic impedance tuning.

adjusted by changing the horizontal step size of the movement (for example, with minimum phase steps of 0.013 to 0.026 deg. possible at 1800 MHz). Tuners operating at higher frequencies (models up to 65 GHz have been manufactured using the same concept) use a lower step size, down to 3 µm.

In evaluating an impedance tuner, two performance barometers are of interest—the mechanical repeatability, which can be expressed in terms of measured quantities (such as S_{11} and S_{21}) that are obtained between repeated settings of the tuner motors and the tuning accuracy, which is the vector difference between a tuned impedance and the value measured by the VNA.

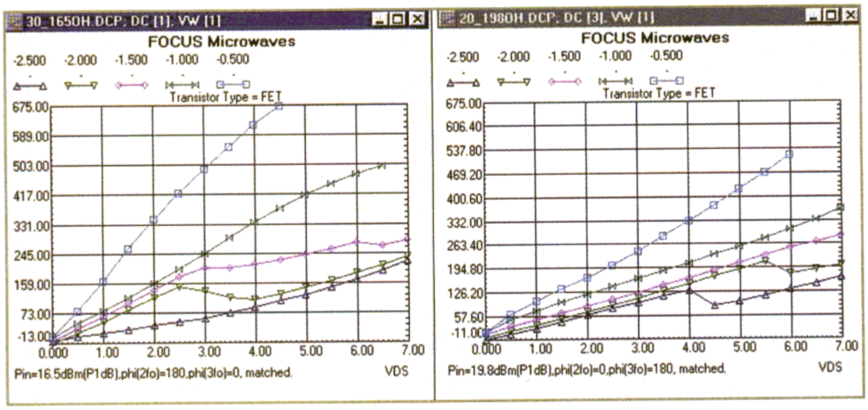
For testing the tuning accuracy of a harmonic tuner, the tuner is calibrated at a number of points, typically 20 × 20 = 400 points or 40 × 40 = 1600 points. The first number of points represents the positions of the second-harmonic resonators, while the second number of points represents the positions of the third-harmonic resonators **(Fig. 4)**. A special measurement routine is then executed, where the phase of S_{11} (for $2f_0$) and S_{11} (for $3f_0$) are swept in equal-phase steps between 0 and 360 deg., using step sizes varying between 1 and 10 deg. It should be noted that these are not calibrated points. Rather, they are interpolated points since, even at the highest calibration density, the distance between calibrated points is at least 9 deg. (360 deg./40 points). As an example, the tuning accuracy of a harmonic tuner is shown in **Fig. 5**, using a test frequency of 870 MHz and tuning $2f_0$. The evaluation, with a calibrated phase step of 9 deg. and a measurement phase step of 2 deg., reveals maximum errors of 0.23 deg. at $2f_0$ and 0.65 deg. at $3f_0$.

The harmonic tuners were installed in a compact load-pull measurement system **(Fig. 2)**. The test system includes up to two harmonic tuners (for source and/or load-pull testing) and two fundamental frequency tuners, generally used with a prematching configuration for high VSWRs (up to 150:1). All of the test-equipment components and associated general-purpose-interface-bus (GPIB) instruments are controlled by a desktop personal computer (PC).

The test system was used to capture the data of **Fig. 6** for a high-power bipolar transistor. Figure 6 shows the effect of harmonic loads on the hot IV curves of the transistor. For these "hot" measurements, the IV characteristics have been measured as the transistor is injected with nominal RF power-sufficient input power to drive the device into 1-dB gain compression. The lefthand plot shows the IV curves under full-load conditions, with the source and load power-matched at the fundamental frequency (f_0) of 1.7 GHz, the second-harmonic source impedance (Z_0) equal to the second-harmonic load impedance for an open circuit [$Z_S(2f_0) = Z_L(2f_0) = \infty$], and the third-harmonic source impedance equal to the third-harmonic load impedance for a short circuit [$Z_S(3f_0) = Z_L(3f_0) = 0$].

The righthand plot of **Fig. 6** shows the IV curves for the bipolar transistor under matched conditions, but with reversed conditions for the second- and third-harmonic source and load impedances {i.e., with the second-harmonic source impedance equal to the second-harmonic load impedance for a short circuit [$Z_S(3f_0) = Z_L(3f_0) = 0$] and the third-harmonic source impedance equal to the third-harmonic load impedance for an open circuit [$Z_S(2f_0) = Z_L(2f_0) = \infty$]}. A difference in the collector current of 50 percent can be observed by swapping the harmonic loads from open to short circuit.

The harmonic tuners can enhance transistor output power, intermodulation (IM), and PAE. When the test system of **Fig. 2** was used to evaluate PAE, it was found that tuning of the second-harmonic impedances resulted in a 20-percent increase in PAE, whereas third-harmonic tuning resulted in a PAE improvement of about 3 percent. **MRF**



6. These hot IV curves were measured with the help of harmonic tuners, first using open-circuit second-harmonic impedance and short-circuit third-harmonic impedance (left) and then short-circuit second-harmonic impedance and open-circuit third-harmonic impedance (right).

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Modern Signal Generators Emulate Complex Waveforms

The latest synthesis techniques combined with advanced modulators result in the availability of signal generators that are accurate, flexible, and easy to use.

JACK BROWNE
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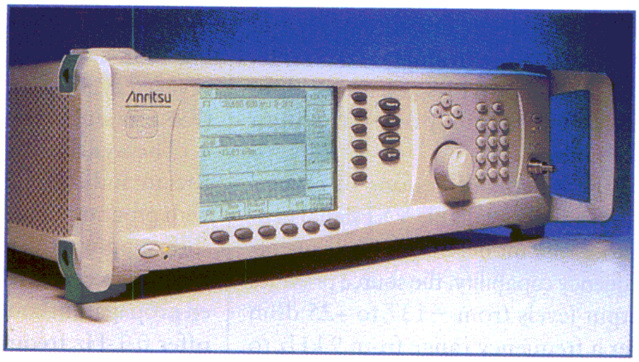
Signal generators have evolved rapidly in recent years, in response to the dramatic changes in communications systems during the 1990s. As a result, modern signal generators must often incorporate a wide range of analog and digital modulation capabilities in addition to functions such as frequency sweeps and power sweeps. And phase noise, spurious noise, and harmonics must be almost negligible to perform accurate measurements of phase-modulated systems and their components.

Signal generators were once categorized as being either RF or microwave units, although several models are now available that cover RF and microwave applications. The newly announced model MG3690A frequency synthesizer from Anritsu Co. (Morgan Hill, CA), for example, combines the bandwidths of RF and microwave signal generators in a single housing **(Fig. 1)**. The unit operates from 0.1 to 40 GHz with 0.1-Hz frequency resolution. It features leveled output power from −129 to +17 dBm, adjustable in 0.01-dB steps. By integrating a digital downconverter into the MG3690A, the generator achieves low phase noise across its full operating range.



1. The MG3690A RF/microwave frequency synthesizer offers a broadband frequency range of 0.1 Hz to 40 GHz with low phase noise and various sweep modes. (Photograph courtesy of Anritsu Co., Morgan Hill, CA.)

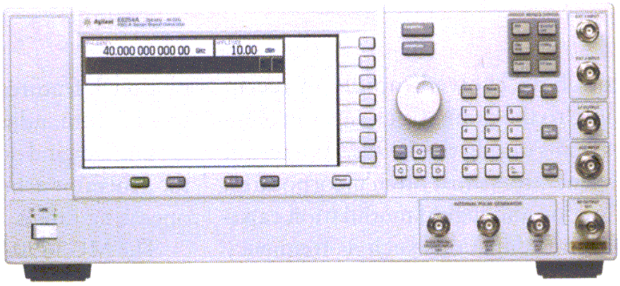
The MG3690A (Fig. 1) combines the bandwidths of separate RF and microwave signal generators with the spectral purity and frequency stability of a phase-locked source. The measurement-grade synthesizer achieves frequency resolution of 0.1 Hz from 0.1 Hz to 40 GHz, with leveled output power that is adjustable in 0.01-dB steps from −120 to +17 dBm (with an option).

The broadband synthesizer combines a low-noise yttrium-iron-garnet (YIG) oscillator as the source of fundamental frequencies, a digital downconverter (DDC) module to generate low-noise signals from 10 MHz to 2.2 GHz, and a 48-b numerically controlled oscillator (NCO) to achieve the high-frequency resolution. The architecture includes several phase-locked loops (PLLs) for stability, along with an automatic-level-control (ALC) circuit that provides leveled output power over the wide amplitude range. The DDC produces signals below 2.2 GHz with successive binary division of the YIG oscillator; each division reduces phase noise.

The single-sideband (SSB) phase noise of a standard MG3690A is −88 dBc/Hz offset 1 kHz from a 6 GHz or lower carrier, rising to −75 dBc/Hz phase noise offset 1 kHz from carriers of 20 to 40 GHz. At 100 kHz from the carrier, the phase noise is −102 dBc/Hz when measured from a 6-

GHz carrier and better than −100 dBc/Hz when measured from carriers to 20 GHz. An option provides improved phase noise of −101 dBc/Hz offset 100 Hz from a 500-MHz carrier and −142 dBc/Hz offset 1 MHz from the same carrier frequency. At a 6-GHz carrier frequency, the phase noise with this option is −107 dBc/Hz offset 1 kHz from the carrier and −130 dBc/Hz offset 1 MHz from the same carrier.

The MG3690A can be used as a continuous-wave (CW) source of single RF and microwave frequencies, or as a swept source, sweeping frequency, power, or both. As a CW source, it features up to 20 independent markers, allowing an operator to set as many as 20 independent CW frequencies. As a sweeper, sweep widths with the MG3690A can be set from as narrow as 1 kHz (0.1 Hz with option 11) to as wide as the full frequency range (40 GHz). The number of sweep steps can be adjusted from 1 to 10,000, with every frequency step in the range phase locked. The MG3690A also offers a list sweep mode, controlled through the front panel or remotely by general-purpose interface bus (GPIB). It provides for up to four data tables with 2000 nonsequential frequency/power sets to be stored in memory and then addressed as a phase-locked step sweep. The MG3690A can also perform a basic frequency-hopped or frequency-agile function under GPIB control.



2. The PSG Performance Signal Generator line of sources includes synthesizers with frequency coverage as wide as 250 kHz to 40 GHz with 0.01-Hz resolution. (Photograph courtesy of Agilent Technologies, Inc., Santa Rosa, CA).

In addition to the MG3690A, the firm offers a wide range of analog and digital signal generators for frequency coverage through 65 GHz, including the digital modulation model MG3681A which is a digital modulation signal generator designed for frequency coverage from 250 kHz to 3 GHz. The source offers amplitude-modulation (AM) and frequency-modulation (FM) analog modulation as well as a wideband in-phase/quadrature (I/Q) modulator for creating advanced digital modulation formats.

On a humbler scale, low-cost signal sources from April Instrument (Sunnyvale, CA) are designed as basic measurement tools for the test laboratory and limited production environments. The company's model 8001 signal generator, for example, operates from 2 to 8 GHz with 1-MHz resolution and ±15-MHz frequency accuracy. Frequency-switching speed is 350 ms in full-band normal mode and less than 20 ms in a fast-switching mode. Spurious content is typically −50 dBc, while leveled output power is typically +13 dBm. The source includes TTL-compatible remote control and FM at rates of DC to 200 kHz.

The company's model 8002 extends this frequency range from 2 to 10 GHz, with at least +10-dBm output power and typically +13-dBm output power, while the model 8004 features 1-MHz frequency resolution and ±10-MHz frequency accuracy from 2 to 26.5 GHz. Model 8004 provides at least +8-dBm unleveled output power through 26.5 GHz.

IFR Systems offers one of several commercially available VXI signal generators, the model 3002. With swept-frequency capability, the source provides output levels from −137 to +25 dBm over a frequency range from 9 kHz to 2.4 GHz. The VXI plug-&-play-compatible generator includes a modulation source with sine-wave, square-wave, and triangle-wave capability for generating AM, FM, phase-, pulse-, and FSK-modulation formats.

The firm also offers conventional signal generators with either analog or digital modulation capabilities, as well as the novel dual-source model 2026Q with two independent 10-kHz-to-2.4-GHz signal generators. The 2026Q is designed for multi-tone generation for code-division-multiple-access (CDMA) interference testing.

IFR's analog-modulation 2030 series includes models 2030, 2031, and 2032. Model 2030 operates from 10 kHz to 1350 MHz, model 2031 operates from 10 kHz to 2700 MHz, and model 2032 operates from 10 kHz to 5400 MHz. The sources offer 0.1-Hz frequency resolution, AM, FM, and GPIB programmability.

The company's digital modulation 2050 series includes the models 2050, 2051, and 2052. Model 2050 operates from 10 kHz to 1350 MHz, model 2051 operates from 10 kHz to 2.7 GHz, and model 2052 operates from 10 kHz to 5.4 GHz. These sources feature DC- or AC-coupled standard FM (1-MHz bandwidth) and wideband FM (10-MHz bandwidth) modes. In addition to the two FM modes, the 2050 series also offers phase modulation, AM, and pulse modulation, and accepts digital input signals through a 10-MHz-wide I/Q input port. It converts these digital input signals to quadrature-amplitude-modulation (QAM), phase-shift-keying (PSK), Gaussian minimum-shift-keying (GMSK), or frequency-shift-keying (FSK) modulation formats.

The synthesizers have a built-in Rician and Rayleigh fading simulator with programmable path ratio. Doppler shift supports the testing of communications receivers (Rxs) under simulated propagation conditions. The sources offer 0.1-Hz frequency resolution, an output-power range of −144 to +13 dBm in analog mode, and peak-envelope-power levels of −138 to +6 dBm in digital modulation mode. Output

Continued on page 114

Continued from page 114

levels can be set with 0.1-dB resolution. Nonharmonic spurious levels are less than −70 dBc and phase noise of less than −116 dBc/Hz offset 20 kHz from a 470-MHz carrier.

IFR also offers owners of analog signal generators a cost-effective transition to digital modulation through the model 2029 vector modulator. The vector modulator, which can be used from 800 to 2510 MHz, includes a wideband I/Q modulator with bandwidth in excess of 10 MHz and a built-in arbitrary waveform generator is equipped with 14-b digital-to-analog converters (DACs) operating between 35 and 66 MSamples/s. The modulator is assisted by RF level-control circuitry which allows the 2029 to provide output-power levels from −138 to 0 dBm with a resolution of 0.01 dB and RF-level accuracy of typically better than ±0.25 dB.

The 2029 vector modulator achieves a noise floor of −138 dBc/Hz when modulated with an arbitrary-waveform-generator (AWG) file having a value of +0.2-VDC root mean square (RMS) of full scale. The noise floor improves with increasing drive levels. The 2029 exhibits adjacent-channel power (ACP) of typically −70 dBm for an IS-95 pilot-channel file with a crest factor of 5.5 dB, which has been optimized for ACP.

The 6060A series of synthesized RF signal generators from Giga-tronics (San Ramon, CA) was originally developed by Fluke (Everett, WA) to meet the needs of low-phase-noise measurement applications. Model 6061A operates from 10 kHz to 1050 MHz with 10.00-Hz resolution. It features an output-level range of −127 to +13 dBm that is adjustable with 0.1-dB resolution. The 6061A offers amplitude accuracy of ±1 dB from −127 to +13 dBm along with AM and FM capability. The model 6062A operates from 100 kHz to 2100 MHz with 10-Hz resolution to 1050 MHz and 20-Hz resolution from 1050 to 2100 MHz. It has an output-level range of −127 to +16 dBm at frequencies to 1050 MHz and up to +13 dBm for frequencies to 2100 MHz. The output level is adjustable with 0.1-dB resolution. In addition to AM and FM, the model 6062A offers pulse and phase modulation capabilities.

Giga-tronics also offers a VXI microwave synthesizer, the series 50000A. The two-slot synthesizer module is designed to work with a model 52000A single-slot VXI control module to form a flexible and accurate frequency-synthesizer system. Based on a YIG-tuned source, the VXI synthesizer series can be specified in 11 different frequency configurations totalling 0.01 to 20 .0 GHz. The synthesizers offer 1-Hz frequency resolution and more than +9-dBm leveled output power through 20 GHz, adjustable with 0.1-dB resolution. The phase noise is less than −97 dBc/Hz offset 100 kHz from a 2-to-20-GHz carrier.

In addition, the company's latest synthesizer line—the 12000A series—includes models with coverage of 2 to 8 GHz, 10 MHz to 8 GHz, 2.0 to 20 GHz, and 10 MHz to 20 GHz. Frequency resolution of 0.1 Hz is standard, with an output-power range of −20 to +20 dBm adjustable in 0.01-dB steps. The synthesizers offer CW and list-mode frequency-switching formats. The frequency-switching speed in the CW model is less than 35 ms to within 1 kHz of a new frequency. In list mode, the frequency-switching speed is less than 500 μs to settle within 1 kHz of a new frequency.

Easily the most diversified line of RF and microwave signal generators belongs to Agilent Technologies (Santa Rosa, CA). As with several other suppliers, the firm offers a VXI synthesizer, the model E6432A, which operates from 10 MHz to 20 GHz with 1-Hz resolution. The C-size VXI module features an amplitude range of −90 to +17 dBm, less than 400 μs frequency-switching speed, AM, FM, pulse modulation, and

typically less than −70-dBc spurious content.

The company's 83750 series of synthesized sweepers provides frequency coverage to 20 GHz with 2-MHz swept-frequency accuracy and 1-Hz frequency resolution. The synthesizers provide up to +17-dBm output power at 20 GHz. The 83750 series features a 25-dB power-sweep range and an internal pulse generator.

Agilent's 8360 family of synthesized swept-signal and CW signal generators includes models for coverage from 10 MHz to 50 GHz. The sources offer calibrated output power from −110 to +20 dBm with typically better than −50-dBc harmonics at 26.5 GHz. The phase noise is better than −80 dBc/Hz offset 10 kHz from a 10-GHz carrier. The standard frequency resolution for these models is 1 kHz, with 1-Hz resolution available as an option.

The company's model 8645A is a frequency-agile signal generator that operates from 252 kHz to 1030 MHz, with optional coverage available to 2060 MHz. It features frequency-switching speed of 15 µs, making it suitable for testing frequency-agile radios and surveillance Rxs. The generator can be used to create complex signal simulations that combine several modulation types. The fast-hop mode activates a frequency-locked loop to enable frequency switching as fast as 15 µs from 128 to 2060 MHz, 85 µs from 8 to 2060 MHz, and 500 µs below 8 MHz. The frequency accuracy is better than ±2 PPM while in fast-hop mode. At each frequency, a specified amplitude can be assigned within a 20-dB range. For frequency-agile applications, up to 4000 frequencies can be loaded into the synthesizer's internal memory, with sequences of as many as 8000 frequencies specified. Modulation, such as AM and FM, can also be added during fast-hop mode.

In the RF range, Agilent offers a variety of synthesized signal generators with analog and digital modulation formats. The 8648A/B/C/D series of economy signal generators is designed for general-purpose applications from 9 kHz to 4000 MHz. Model 8648A operates from 100 kHz to 1000 MHz, model 8648B operates from 9 kHz to 200 MHz, model 8648C operates from 9 kHz to 3200 MHz, and model 8648D operates from 9 kHz to 4000 MHz. The frequency resolution for all models is 0.001 Hz (with display resolution of 10 Hz). Typical frequency-switching speed is less than 100 ms. The signal sources deliver better than −136 to +10 dBm output levels across all operating-frequency ranges with 0.1-dB displayed output-level resolution. Harmonic content is less than −30 dBc, while spurious content is less than −60 dBc. The phase noise offset 20 kHz from a 500 MHz carrier is less than −120 dBc/Hz.

For high RF performance, the company offers the 8643A from 0.252 to 1030 MHz (with optional coverage to 2060 MHz), the model 8644B from 0.252 to 1030 MHz (with optional coverage to 2060 MHz), the model 8664A from 0.1 to 3000 MHz, the model 8665A from 0.1 to 4200 MHz, and the model 8665B from 0.1 to 6000 MHz. These sources feature AM, FM, and pulse modulation, and phase noise of less than −130 dBc/Hz offset 20.0 kHz from a 1-GHz carrier for the 8643A and phase noise of less than −136 dBc/Hz offset 20 kHz from a 1-GHz carrier for the 8644B.

The 8662A and 8663A synthesized signal generators are designed for applications requiring very-low absolute phase noise. The 8662A operates from 10 kHz to 1280 MHz while the 8663A operates from 100 kHz to 2560 MHz, both with 0.1-Hz frequency resolution. They achieve less than −147-dBc/Hz phase noise offset 10 kHz from a 120-MHz carrier, spurious-signal levels of generally less than −90 dBc, and a level range of −140 to +13 dBm with 0.1-dB resolution. Both generators offer AM, FM, phase, and pulse-modulation capabilities.

Several years ago, the firm launched its ESG lines of analog and digital signal generators to provide affordable solutions for older systems employing analog modulation (such as AM, FM, and phase modulation), as well as newer systems incorporating complex digital modulation based on the combination of I and Q modulation components. The instruments are designed for reasonably quick frequency-switching speed, low phase noise, generous output power, and high-frequency resolution for bench and production-line testing.

For evaluating older communications systems and their components, the ESG-A and ESG-AP series instruments are designed for those applications requiring conventional analog modulation, such as AM, FM, and phase modulation. The ESG-A line includes the 250-kHz-to-1000-MHz model E4400B, the 250-kHz-to-2000-MHz model E4420B, the 250-kHz-to-3000-MHz model E4421B, and the 250-kHz-to-4000-MHz model E4422B. With somewhat better phase noise, the ESG-AP series includes the 250-kHz-to-1000-MHz model E4423B, the 250-kHz-to-2000-MHz model E4423B, the 250-kHz-to-3000-MHz model E4425B, and the 250-kHz-to-4000-MHz model E4426B. Standard output levels are −136 to +13 dBm from 250 kHz to 1000 MHz, with −13- to +10-dBm output power available through 3000 MHz. An option boosts output power to +16 dBm through 3000 MHz.

The difference in phase noise between the two signal-generator versions is considerable. For example, at 500 MHz, the phase noise for the ESG-A models is −120 dBc/Hz offset 20 kHz from the carrier, but a miniscule −138 dBc/Hz under the same conditions for the ESG-AP models. At 1000 MHz, the phase noise for the ESG-A models is −116 dBc/Hz offset 20 kHz from the carrier, but less than −134 dBc/Hz under the same conditions for the ESG-AP models.

The ESG-D and ESG-DP series of digital signal generators provides similar phase noise and electrical performance to their analog counterparts, but adds full digital modulation capabilities for recreating the complex modulation formats found in systems such as time-division-multiple-access (TDMA) and CDMA cellular systems. The ESG-D series includes the 250-kHz-to-1000-MHz model E4430B, 250-kHz-to-2000-MHz model E4431B, the 250-kHz-to-3000-MHz model E4432B, and the 250-kHz-to-4000-MHz model E4433B. The ESG-DP series includes the 250-kHz-to-1000-MHz model E4434B, the 250-kHz-to-2000-MHz model E4435B, the 250-kHz-to-3000-MHz model E4436B, and the 250-kHz- to-4000-MHz model E4437B. The sources include an I/Q modulator with 20-MHz bandwidth in addition to capabilities for producing wideband AM, FM, and phase modulation. An optional internal dual AWG is available for producing statistically accurate waveforms from files created in mathematical modeling programs, such as Matlab.The arbitrary waveform generator features 14-b DAC resolution. In addition, the ESG-D and ESG-DP signal sources are available with firmware personalities for testing according to

Continued on page 137

RF power transistors from the mechanical side

DEFINING THE SPECIFICATIONS for an RF power transistor usually focuses on the device's electrical performance, but its mechanical structure is also an important factor in reliability and cost. While a designer may not have control over how the transistor is manufactured, it is important to understand which fabrication methods and mechanical specifications can impact its operation in the field. These factors are explained in a five-page application note from M/A-COM entitled "Specifying RF Power Transistors."

The principal advice for the designer is not to load down a specification with process requirements and test parameters that add no value to the transistor, but do increase its cost. Subject areas covered in the note include how the die is mounted; wirebonding; capping (lid attachment); and tests such as temperature cycling, fine- and gross-leak testing, DC test, RF test, and burn-in. Of course, the specification must reflect the end application of the device. For example, fine- and gross-leak tests are used to check the hermiticity of a sealed cavity, but if a hermetically-sealed transistor is not required, neither is the test unless it is routine in the manufacturing process.

Temperature cycling (thermal shock) is a worthwhile test for transistors expected to serve in high-reliability applications. Temperature cycling subjects the transistor to the stresses it may experience in the field and is also a good indicator of any mechanical weak points in the wirebonds, lid, and package-solder combinations. DC testing can consist of a tricky set of specifications because, as the note points out, "over specifying can be like painting yourself into a corner." A designer should decide beforehand which parameters are important to performance in the application. If there is any doubt about a parameter, it should be measured and recorded in case problems arise later.

In the matter of RF testing, the note states that it is a very complex and important subject since the test circuit and test conditions exert much influence over many transistor parameters. Therefore, designing a high-quality test circuit enables key performance parameters to be identified and specified from the beginning.

The note is included in a recently issued CD-ROM that contains a large number of application notes covering semiconductors, passive components, and other topics.

M/A-COM, 1011 Pawtucket Blvd., Lowell, MA 01853; (800) 366-2266, Internet: www.macom.com.

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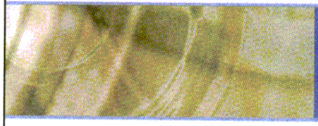

Temperature cycling (thermal shock) is a worthwhile test for transistors expected to serve in high-reliability applications.

An introduction to the digital radio Rx

A MULTICHANNEL DIGITAL radio Rx is a device that offers the benefits of cost reduction and the use of digital, rather than analog, techniques in wireless base-station architectures. Before embarking on the design of this type of Rx, however, there are a number of fundamental concepts about this technology that should be understood. That is the goal of a nine-page application note entitled "Basics of Designing a Digital Radio Receiver (Radio 101)" from Analog Devices.

As the note states, its focus is the radio rather than the DSP and how to predict and design it for the necessary performance. Since ADCs are central to a digital Rx, the note begins with the concepts of Nyquist and those of over and undersampling. The high sampling rates that are made possible by advanced ADC devices lead to a low noise floor and the reduction of noise and spurious signals in the radio through digital filtering.

What kind of performance can a designer expect from such a radio? This is where the note begins with an analysis that starts at the antenna and ends at the digital tuner/filter—the last stage before the DSP. Reducing noise is critical to radio performance, so the first item to be considered is the available noise power at the antenna. The analysis proceeds through successive stages to explain the idea of cascaded noise figure, how to calculate the total noise present in the ADC, how the technique known as dither can improve spurious-free dynamic range, and how noise voltage contributes to the overall performance of the ADC. Other important areas covered include IP3, clock jitter in ADCs, and phase noise. The note is included in a CD-ROM known as "Advanced Signal Processing for Wireless."

Analog Devices, Inc., Three Technology Way, Norwood, MA 02062; (781) 329-4700, Internet: www.analog.com

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cover story

This highly integrated GPS Rx IC improves upon an earlier-generation device by including more components in a smaller package with a reduction in power consumption.

Low-Power IC Packs GPS Receiver

Global Positioning System (GPS) receivers (Rxs) have proven to be tremendous time-saving devices, as well as invaluable safety tools, when position location is required in an emergency. Five years ago, California Eastern Laboratories (CEL) [Santa Clara, CA] and NEC (Tokyo, Japan) made a huge impact on the design of handheld GPS Rxs through a highly integrated GPS Rx integrated circuit (IC). But with the increased demand for embedded GPS functionality in personal digital assistants (PDAs) and cellular telephones, the firms have redefined the state of GPS integrated circuitry through the development of the model UPB1007K GPS Rx IC, which is smaller and more integrated than previous-generation GPS Rx ICs. The UPB1007K, which is supplied in a 36-pin QFN package, consumes only 75 mW of power when running on a single +3-VDC supply.

The first venture by CEL/NEC into GPS integration—the UPB1004GS Rx IC—found its way into the *GPS2000 Satellite Navigator* from Magellan Systems Corp. (San Dimas, CA), helping the compact Rx become the first handheld GPS unit to sell for less than $200. Today, these Rx ICs are found in many applications besides GPS handsets. They are installed in dashboard navigation systems, asset-tracking systems, satellite-dispatch systems and, most recently, in PDAs and cellular handsets.

Regarding cellular systems, recent Federal Communications

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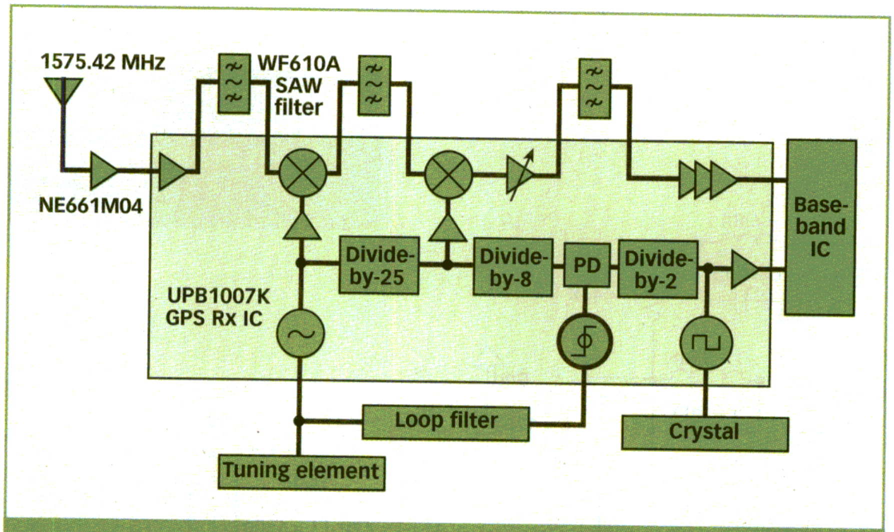


1. The UPB1007K GPS Rx IC features an on-chip frequency synthesizer, LNA, and crystal-oscillator circuitry for low-power reception of GPS signals.

Commission (FCC) regulations have mandated the introduction of enhanced-911 (e-911) call-location functionality. Cellular carriers will be required to provide latitude and longitude data—known as Automatic Location Identification (ALI)—to all public-service answering organizations that receive emergency calls from cellular users. To comply, carriers are looking at GPS-enabled handsets, network-based solutions, or a combination of both. To date, approximately half have announced they will opt for the GPS-enabled handsets.

Location-based services (LBS) is another emerging market that is driving the development of GPS-enabled handsets. A sample scenario would involve two cellular users determining a meeting point or selecting a restaurant location through the LBS capability. LBS services are available now on a limited basis in Europe and Japan—with global revenues expected to grow from $1.6 billion last year to $40.7 billion in 2006.

PDA manufacturers are also looking at GPS. With screens that are larger and more colorful than those of their cellular cousins, PDAs seem like the ideal vehicle for displaying GPS-based information. But PDA manufacturers are wary of widespread acceptance for GPS. Not yet convinced of the demand for GPS services, their approach is to provide GPS functionality in add-on external modules, which are rather embedded in their PDA chip sets.

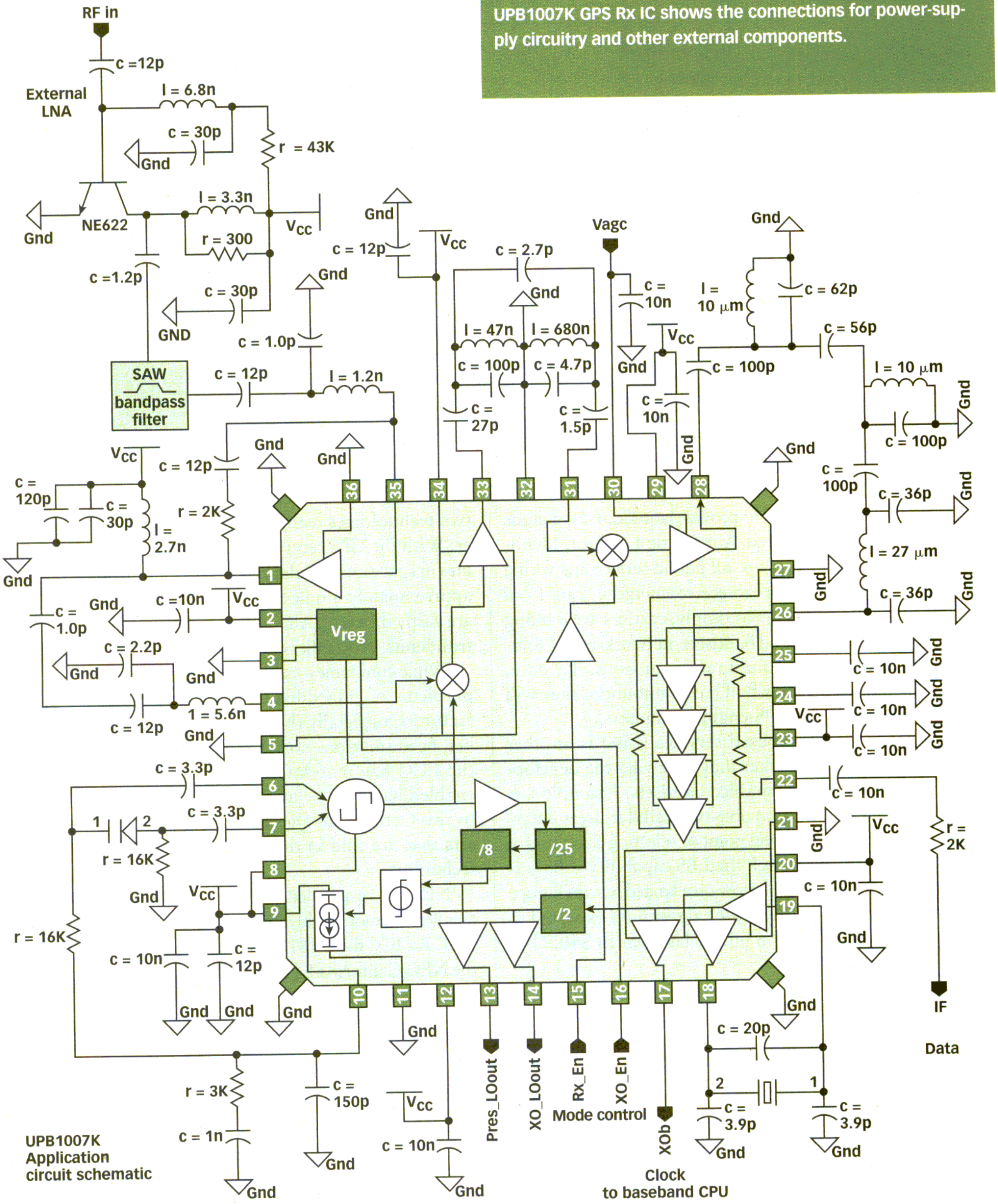
Cellular-system designers have issues with embedded GPS as well. The fact is that the two technologies really do not fit well together. With the GPS receiving signals from satellites in space and cellular receiving signals from approximately a mile away, the power levels are vastly different. Also, with two different RF front ends, crosstalk is a major concern.

While companies are working on solving the problems of embedded GPS, handset manufacturers, especially those in the cellular market, need solutions now. In the case of e-911, the FCC has mandated that the new ALI-enabled handsets be available on the market by this October. By December 2002, *all* handsets that are sold in the US must include the technology.

NEC has responded with a new GPS Rx IC. Smaller and more highly integrated than previous NEC Rx ICs, the UPB1007K was developed at the NEC/California Eastern Laboratory Design Center (Santa Clara, CA) and is fabricated at NEC facilities in Japan using NEC's latest ultra-high-speed UHS0 25-GHz transition-frequency bipolar process. The high-cutoff-frequency process results in good gain figures at very low bias, and much lower current consumption than earlier Rx ICs—only 25 mA, which is currently the lowest on the market for a device offering the UPB1007K's level of integration.

Another benefit of the UHS0 process is that it has PNP and NPN transistors in a vertical structure. This enables the IC designer to configure high-frequency charge-pump circuits in the device. There are many advantages to using charge-pump circuitry. First, its constant amplitude signal has a duty cycle that is directly related to the phase difference between the local oscillator (LO) and the crystal reference. Therefore, unlike loop amplifiers that are "on" at all times to drive the varactor, the charge pump consumes only as much current as required to correct the phase error. Once the LO is locked to the crystal reference—barring any major system disruption — very little current is used.

2. This typical application schematic diagram for the UPB1007K GPS Rx IC shows the connections for power-supply circuitry and other external components.



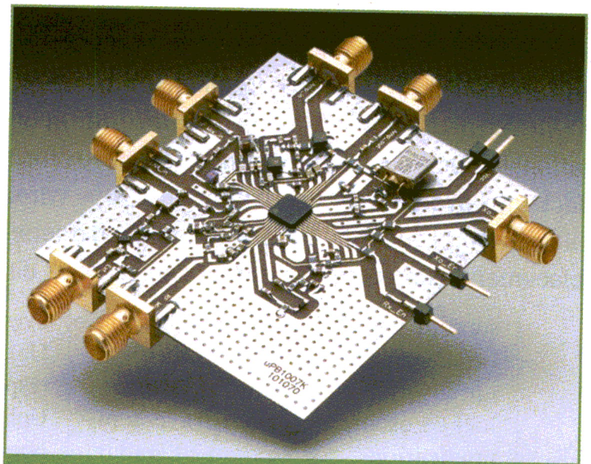
> **The UHS0 process** results in improved noise figures which has enabled NEC to integrate the LNA on-chip with remaining GPS Rx circuitry.

Charge pumps also support a simplified loop-filter circuit, resulting in fewer components and a more compact system design. In the UPB1007K **(Fig. 1)**, the charge pump is driven by a flip-flop-based digital phase detector, a scheme that was chosen due to its insensitivity to incoming power levels from the LO or crystal oscillator—and its digital output is suitable to run the charge pump.

The new UHS0 process also results in improved noise figures which, in turn, has enabled NEC to integrate the low-noise amplifier (LNA) on-chip with the remaining GPS Rx circuitry. This means that applications that employ active antennas can now feed signals directly into the UPB1007K. With the addition of one external single-stage LNA, such as the NE661M04 from CEL/NEC, excellent sensitivity can also be achieved with passive antennas. The on-chip LNA features cascode architecture for higher gain and lower power consumption than a cascade scheme: 2.5 mA, with a noise figure of less than 3 dB and an associated gain of 15 dB.

In addition to the LNA, the GPS chip includes an integrated mixer, a voltage-controlled oscillator (VCO), and crystal oscillator. Besides the obvious savings in real estate, the integration of these last two functions helps improve frequency stability, resulting in less frequency pulling on the phase-locked loop (PLL) and the phase detectors. This crystal oscillator also features a buffered output, which allows it to be used to time the central processing unit (CPU). This eliminates the need for a second crystal oscillator, which simplifies the design, saves space, and reduces power consumption. And since the crystal oscillator and Rx power-down circuitry are separate, the Rx can be turned off when no GPS reception is required, while the crystal oscillator continues to drive the CPU.

The UPB1007K features a superheterodyne dual downconversion Rx architecture. The Rx is designed to process 1575.42-MHz signals from the antenna through either a discrete LNA or the onboard LNA. The signals are downconverted to a first intermediate frequency (IF) of 61.38 MHz by mixing with the 1636.8-MHz signals from the onboard LO. The LO is also used to create a second set of signals at 65.472 MHz for the second downconversion process, which results in a typical second IF of 4.092 MHz.



3. The UPB1007K GPS Rx IC can be used with an evaluation board that contains all of the required RF and IF filtering as well as an external LNA.

The onboard crystal oscillator generates a set of 16.3667-MHz reference signals which are sent with the second IF signal to the GPS system's digital signal processor (DSP) for analysis and subsequent display on the system's screen.

The RF downconversion chain features 36-dB typical power-conversion gain, delivering a maximum first IF output power of −5 dBm. The LO leakage at the IF or RF point is below −45 dBm, while the single-sideband (SSB) noise figure is typically 3.5 dB for an RF input-power level of −40 dBm.

The IF downconversion chain, with a minimum 40-dB voltage-gain-control range, features typical second IF output levels of 1.2 V_{PP} into a 2-kΩ load. The LO leakage at the first and second IF pin is typically −80 dBm minimum. The second IF amplifier provides an additional 40-dB gain, for total conversion gain through the entire device of 120 dB.

The UPB1007K is supplied in a miniature 36-pin QFN package, which represents a 62-percent reduction in size compared to earlier 30-pin small-shrink-outline-package (SSOP) GPS Rx ICs. It operates on a single +3-VDC supply (approximately 25-mA typical current draw) and is designed for 1575.42-MHz input signals. It translates input signals into 4-MHz baseband output signals. The IC provides typical peak-to-peak output voltage of +1 VDC and achieves more than 120-dB on-chip gain with an automatic-gain-control (AGC) range of 40 dB. The phase noise is only −88-dBc/Hz offset 10 kHz from the carrier. The onboard LNA achieves a typical noise figure of 2.8 dB at 1575 MHz with 15-dB gain.

The GPS Rx IC is rated for operating temperatures from −40 to +85°C. The maximum LO leakage at the RF input pin is −48 dBm. In a typical application **(Fig. 2)**, well-distributed ground pins in each corner maintain good RF integrity, while an external LNA helps maximize Rx sensitivity. An evaluation board is available for the UPB1007K **(Fig. 3)** that combines the IC with RF and IF filtering and an external LNA to simulate a complete GPS Rx. P&A: $5.36 each (10,000 qty.); stock. **California Eastern Laboratories, 4590 Patrick Henry Dr., Santa Clara, CA 95054; (408) 988-3500, FAX: (408) 988-0266, Internet: www.cel.com.**

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YROs Combine Wide Band With High Speed

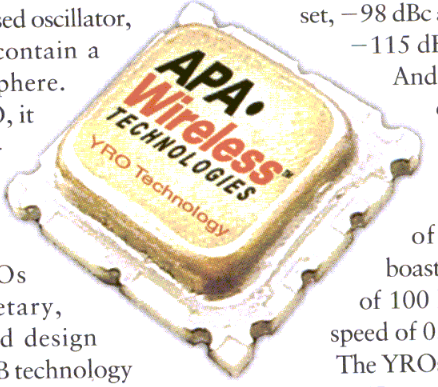
These oscillators have the ample bandwidth of YIG-based oscillators, but are more frequency agile and less susceptible to vibrational effects.

DON KELLER
Senior Editor

YIG-based oscillators are renowned for their ability to generate clean sine waves at very high frequencies, but they are not known for their frequency agility. Nor are they immune to vibrational effects such as microphonics, phase hits, and FM effects. To overcome these limitations, APA Wireless Technologies (Fort Lauderdale, FL) has developed a series of YIG replacement oscillators (YROs) that can serve as direct substitutes for YIGs and DROs in applications such as frequency synthesizers, upconverters, downconverters, phase-locked oscillators, microwave communications, test equipment, radar, LMDS, and MMDS **(see figure)**.

Unlike a YIG-based oscillator, a YRO does not contain a rare-earth alloy sphere. And, unlike a DRO, it does not use a dielectric "puck." There are no mechanical components.

Instead, YROs employ a proprietary, voltage-controlled design using standard PCB technology and pick-and-place components. The result is an oscillator that generates a very clean sine wave at very high frequencies, but is also very frequency agile, relatively immune to vibrational effects, and inexpensive to manufacture.



The YRO can be adapted easily to existing systems.

Like a YIG-based synthesizer, a YRO-based synthesizer can generate frequencies from 10 to 12 GHz at output levels to +8 dBm with only a ±1-dB variation over its operating temperature range. Harmonics are −15 dBc and spurious responses above 10 kHz are −70 dBc. Unlike a YIG-based oscillator, the YRO boasts phase noise levels of −83 dBc at 100-Hz offset, −96 dBc at 1-kHz offset, −98 dBc at 10-kHz offset, and −115 dBc at 100-kHz offset.

And, unlike a YIG-based oscillator, which typically has a minimum step size of 500 kHz and a switching speed of 100 ms, the YRO boasts a minimum step size of 100 kHz and a switching speed of 0.5 ms.

The YROs require a 50- or 100-MHz external reference for full frequency coverage, and draw 300 mA from a single +12-VDC power supply. **APA Wireless Technologies, 4050 NE 5th Ave., Fort Lauderdale, FL 33334; (954) 563-8833, Internet: http:// www.apawireless.com.**

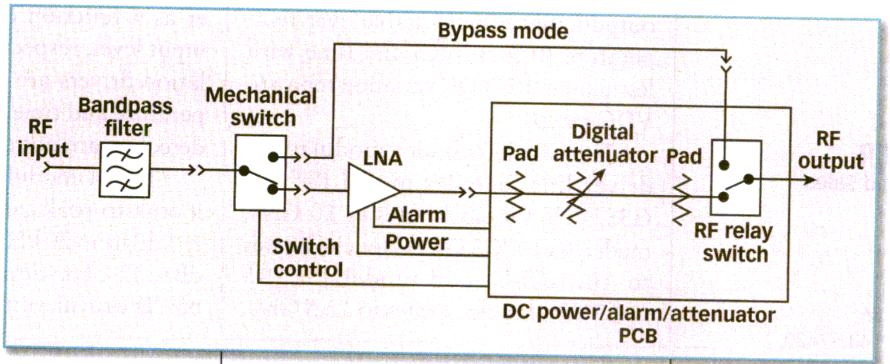
Enter No. 52 at www.mwrf.com

Link Balancers Extend Cellular-Receiver Range

A series of diversity-receive link balancers works with existing base stations to preserve or extend the receive range of AMPS, GSM, and PCS communications systems.

JACK BROWNE
Publisher/Editor

Coverage is a critical requirement in cellular systems. Coverage can be boosted by adding more PAs to a base-station's transmit section. When the Rx's range must also be extended, the simplest solution is the addition of a Link Balancer from Narda (Hauppauge, NY). A Link Balancer can increase the sensitivity of a base station's Rx, while maintaining high linearity. A variety of models is available at cellular and PCS frequencies from 824 to 1910 MHz.



Link Balancers provide high-rejection bandpass filters and a high-linearity LNA to improve the sensitivity of cellular and PCS base-station receive circuitry.

Each Link Balancer includes a bandpass filter with low insertion loss and high rejection of transmit signals, as well as a balanced LNA with a typical noise figure of 1 dB and typical output IP3 of +42 dBm. A mechanical switch **(see figure)** selects a low-loss (typical insertion loss of 2.4 dB) bypass mode in the event of an LNA failure or interruption of DC power.

Link Balancers are available for cellular and PCS frequencies. For example, model 70316A is designed for cellular AMPS A-band receive operation from 824 to 849 MHz. It features a 15-dB gain range that is adjustable in 1-dB steps, with maximum gain variation over temperature of only 1 dB. The typical noise figure is 1.8 dB at +25°C. The Link Balancer achieves an input IP3 of typically +15 dBm. Transmit signals from 869 to 894 MHz are rejected by at least 75 dB.

For PCS frequencies, the model 70318A is designed for A-band receive frequencies from 1850 to 1865 MHz. It achieves a typical noise figure of 2.0 dB at +25°C. The PCS Link Balancer features minimum rejection of 60 dB at 1785 and 1930 MHz. **Narda, an L3 Communications Co., 435 Moreland Rd., Hauppauge, NY 11788; (631) 231-1700, FAX: (631) 231-1711, Internet: www.nardamicrowave.com.** MRF

Enter No. 53 at www.mwrf.com

Modulation Drivers Push Optical Systems To 12.5 Gb/s

This series of extremely stable modulation drivers supports Mach-Zehnder-based optical-communications systems at operating rates to 12.5 Gb/s.

Mach-Zehnder modulation drivers from MITEQ, Inc. (Hauppauge, NY) are built upon the company's expertise in wideband, low-noise-amplifier (LNA) technology and provide clean, stable output voltages that are suitable for error-free transmissions in optical-communications systems operating at rates to 12.5 Gb/s. The new JST modulation driver line features a low-frequency limit of 20 kHz and +7-VDC outputs that remain stable over temperature (0 to +70°C) and time with less than ±0.1-VDC variation for a +6-VDC ramp.

The Mach-Zehnder modulation-driver line includes model JST100 G3S7VPC for clock rates to 10 Gb/s, model JST107G3S7VPC for clock rates to 10.7 Gb/s, and model JST125 G3S7VPC for clock rates to 12.5 Gb/s.

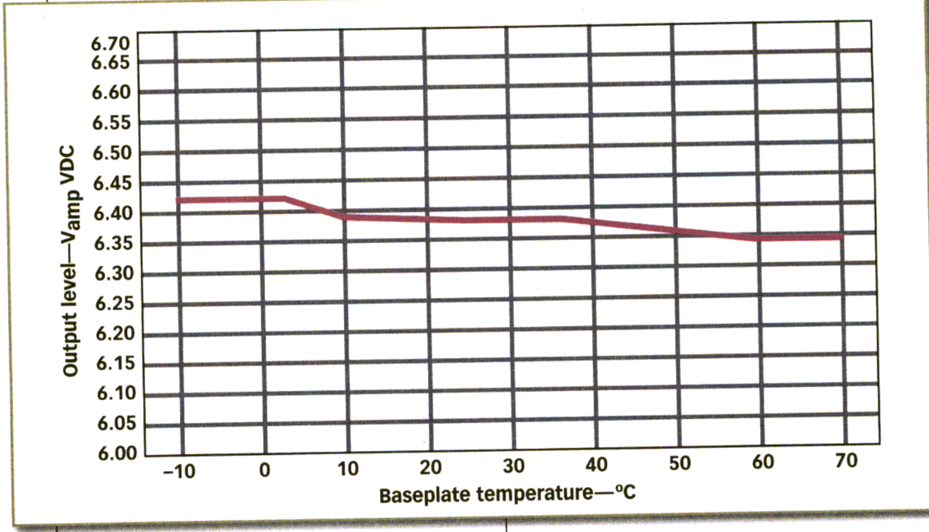
Figures 1 and 2 show typical output voltage performance for a model JST125G 3S7VPC modulation driver as a function of temperature and input level, respectively. These modulation drivers are so stable over temperature and time, in fact, that output detectors are not needed.

The JST modulation drivers exhibit peak-to-peak gain flatness of typically 1 dB from 20 kHz to 8 GHz and ±2.5 dB to 12 GHz with an 800-mV input signal. They achieve input return loss of 10

DAVID KRAUTHEIMER
Director of Marketing and Sales

BOB PFLIEGER
Department Head

MITEQ, Inc., 100 Davids Dr.,
Hauppauge, NY 11788-2086;
(631) 436-7400, FAX: (631) 436-7430,
Internet: www.miteq.com.

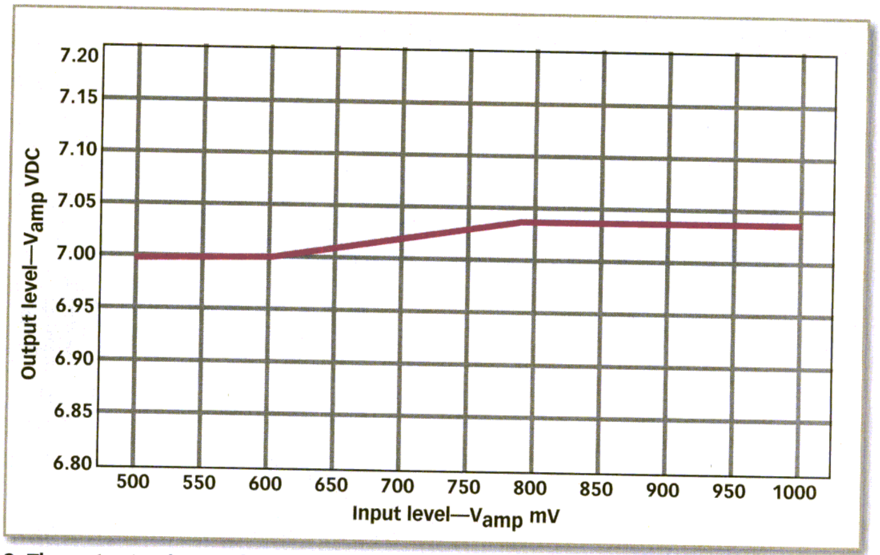


1.The output voltage of a JST series modulation driver is plotted as a function of baseplate temperatures from –10 to +708C.

dB minimum to 12 GHz and output return loss of 10 dB minimum to 12 GHz. They feature maximum jitter of 10 ps, a maximum 10-to-90-percent rise time of 30 ps, and a maximum 10-to-90-percent fall time of 30 ps. The modulation drivers are designed for operating temperatures from 0 to +70°C.

In standard JST models, the output level can be adjusted through a 0- to +15-VDC low-current control voltage. Other versions are available for adjustment through 0- to –15-VDC low-current control voltages. The JST modulation drivers are designed for maximum input voltages to +1.5 VDC.

The MITEQ JST series of light modulator drivers has been fielded in quantities of well over 10,000. They are used to drive various Mach-Zehnder lithium-niobate electro-optic modulators. MITEQ has worked with optical system suppliers and Mach-Zehnder modulator designers to optimize the driver-modulator combination. Light extinction ratios of greater than 13 dB can be achieved over temperature and input-level variations, without requiring driver AGC and without precise MZM bias control.



2. The output voltage of a JST series modulation driver is plotted as a function of input voltages from 500 to 1000 mV.

The devices use hermetic glass-to-metal seals and are seam-welded for environmental protection. MITEQ, Inc., 100 Davids Dr., Hauppauge, NY 11788-2086; (631) 436-7400, FAX: (631) 436-7430, Internet: www.miteq. com.

Enter No. 54 at www.mwrf.com

Laminate Fashions Microstrip Antennas

This ceramic-filled, glass-reinforced laminate material provides the dielectric-constant consistency and low loss needed for high-frequency microstrip antenna applications.

JACK BROWNE
Publisher/Editor

Antenna designers have long sought their own line of high-frequency laminate materials with unique mechanical and electrical requirements. At long last, their supplications have been answered in the form of the RO4232™ high-frequency circuit from Rogers Corp. (Chandler, AZ). Based on the company's successful RO4000™ material line, this ceramic-filled, glass-reinforced hydrocarbon-based circuit-board material features the tightly controlled dielectric-constant consistency and low-loss performance cherished by designers of wireless base-station and other microstrip antennas.

The laminate features a dielectric constant of 3.2 with a tolerance of ±0.05 and a loss tangent (dissipation factor) of only 0.0018 at 2.5 GHz. These values translate into improved antenna gain with low signal loss. Dimensional stability in the X and Y directions is better than 0.05 mils/in. When tested at temperatures from −55 to +125°C, the CTE is typically 20 PPM/°C in the X direction, 17 PPM/°C in the Y direction, and 25 PPM/°C in the Z direction. In fact, the CTE of the RO4232 material is similar in the X and Y directions to that of copper, minimizing cladding stress.

The RO4232 material has a specific gravity of 1.72 at +23°C. It exhibits very low moisture absorption of only 0.05 percent when immersed underwater for 48 hours. This is an indication that the material will hold up well under a wide range of environmental extremes.

RO4232 can be fabricated into PCB antennas using standard FR4 processing techniques. Additionally, the material is also well-suited for use with automated handling systems and scrubbing equipment designed for copper-surface preparation.

The standard RO4232 is supplied in a thickness of 0.060 ±0.004 in. (1.52 ±0.1016 mm). The material is available in untrimmed panel sizes of 50 × 61 in. (1.273 × 1.529 m) and 50 × 122 in. (1.273 × 3.099 m), with electrically certified dimensions of 48 × 60 in. (1.219 × 1.524 m) and 48 × 120 in. (1.219 × 3.048 m). Standard cladding consists of 1-oz. zinc-free copper electrodeposited on both sides of the RO4232 material. **Rogers Corp., Advanced Circuit Materials Division, 100 S. Roosevelt Ave., Chandler, AZ 85226-3415, (480) 961-1382, FAX: (480) 961-4533, Internet: www.rogers-corp.com** MRF

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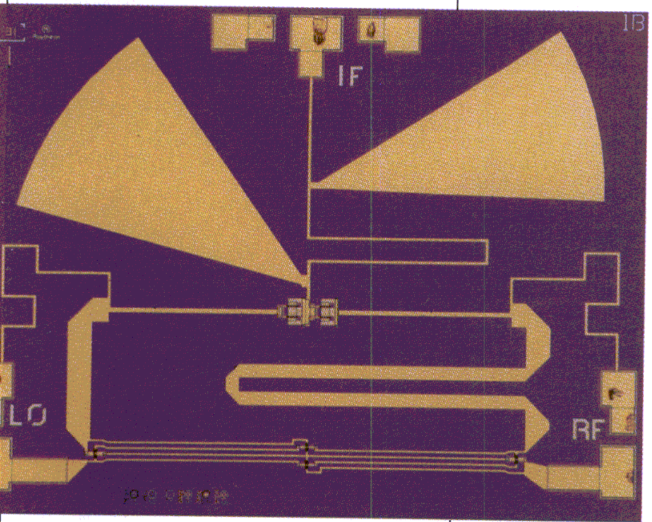
Radio Chip Sets Power Millimeter-Wave Systems

Based on a reliable GaAs PHEMT process, these millimeter-wave chip sets clear the way for high-performance line-of-sight radios at 23, 26, and 38 GHz.

JACK BROWNE
Publisher/Editor

Available bandwidth is scarce at cellular and personal-communications-services (PCS) frequencies, prompting the development of point-to-point and point-to-multipoint communications systems at higher, millimeter-wave frequencies. In support of these communications systems, Raytheon Co.'s RF Components Division (Andover, MA) has made a family of integrated radio chip sets available for line-of-sight communications applications at 23, 26, and 38 GHz. The chip sets include low-noise amplifiers (LNAs), power amplifiers (PAs), and low-noise mixers that can be used as frequency upconverters or downconverters.

The chip components are designed to operate at supply voltages of +4 or +5 VDC, with nominal negative gate voltage on the order of −0.5 VDC. The common supply voltage helps to simplify transmitter (Tx) power-supply requirements. The chip-set components are fabricated with a reliable GaAs pseudomorphic-high-electron-mobility-transistor (PHEMT) process. In addition to the LNAs, PAs, and mixers **(see figure)**, the firm also supplies buffer amplifiers and frequency multipliers.



The millimeter-wave chip sets include GaAs PHEMT mixers designed to be used as frequency upconverters or downconverters.

Each LNA is optimized in terms of small-signal performance and noise, allowing the mixer to be driven without the need for extra amplifier components. The LNAs include the 21.0-to-26.5-GHz model RMWL26001 and the 37-to-40-GHz model RMWL38001. The RMWL26001 is a four-stage design that features 22-dB typical gain from 21 to 26.5 GHz with ±1.4-dB total gain variations with frequency. The typical noise figure is 2.9 dB across the operating frequency range. The amplifier achieves +10-dBm output power at 1-dB compression, with 12-dB input return loss and 12-dB output return loss. The output third-order intercept point (IP3) is +22 dBm. The amplifier draws 80-mA drain current at 1-dB compression and +4 VDC, and 65-mA drain current with −15-dBm input power.

The model RMWL38001 is also a four-stage design that offers 2.7-dB typical noise figure from 37 to 40 GHz, with 22-dB typical gain and 1.5-dB total gain variation with frequency. The LNA, which can handle maximum

The model RMWL38001 is also a four-stage design that offers 2.7-dB typical noise figure from 37 to 40 GHz, with 22-dB typical gain and 1.5-dB total gain variation with frequency. The LNA, which can handle maximum RF input power of +6 dBm, delivers +13.5-dBm output power at 1-dB compression and +15-dBm saturated output power. The amplifier features an output IP3 of +23 dBm, with 12-dB input return loss and 13-dB output return loss. It draws 55-mA drain current at 1-dB compression and +4 VDC, and 50-mA drain current when operating with –20-dBm input power.

The models RMWM26001 and RMWM38001 are 26- and 38-GHz diode monolithic-microwave-integrated-circuit (MMIC) mixers, respectively, that can be used as upconverters or downconverters with only slight differences in conversion loss. Both mixers are designed for use without DC bias. The model RMWM26001 can handle RF input-power levels up to +25 dBm. It has an RF range of 21.0 to 26.5 GHz, a local-oscillator (LO) range of 17.0 to 24.1 GHz, and an intermediate-frequency (IF) range of 4.02 to 4.12 GHz. It is designed for LO drive of typically +12 dBm. The MMIC mixer exhibits 7.5-dB typical upconverter loss, 8.5-dB typical downconverter loss, and typically 2-dB conversion-loss variation with frequency. The mixer has 12-dB typical RF port return loss, 10-dB typical LO port return loss, and 8-dB typical IF port return loss. The LO-to-RF isolation is typically 20 dB, while the LO-to-IF isolation is typically 35 dB. The mixer reaches 1-dB compression at IF port for upconversion with +8-dBm input power and 1-dB compression at RF port for downconversion with +9-dBm input power.

The model RMWM38001 can handle RF input-power levels up to +25 dBm. It has an RF range of 37 to 40 GHz, an LO range of 32 to 35 GHz, and an IF range of 4.7 to 5.3 GHz, with a typical LO drive requirement of +12 dBm. The mixer exhibits 7.5-dB typical upconverter loss, 8.0-dB typical downconverter loss, and typically 3.0-dB conversion-loss variation with frequency.

PAs for the chip sets include the models RMPA19000, the RMPA29000, and the RMPA39000 with frequency ranges spanning 18 to 22 GHz, 27 to 30 GHz, and 37 to 40 GHz, respectively. All three amplifiers are three-stage designs and fabricated with a 0.15-µm gate-length power GaAs PHEMT process.

The RMPA29000 delivers +30-dBm output power at 1-dB compression and +30.5-dBm saturated output power from 27 to 30 GHz. The RMPA39000 measures 4.28 × 3.19 mm and delivers +27-dBm output power at 1-dB compression and +28-dBm saturated

Switch System Aids Microwave Testing

This switching system maintains signal integrity at microwave frequencies and can be integrated transparently into test and evaluation systems.

Common sense dictates that a test instrument requires a level of sensitivity, resolution, and accuracy beyond the limits of the product being tested. But testing high-frequency and microwave RF devices is especially challenging since the quality of measurements depends not only on the instrumentation used, but also on the characteristics of the signal path itself. Inserting connectors, switches, extra cabling, and other devices into an RF circuit can introduce mismatch conditions that result in reflections, signal loss, and degraded measurements. To meet this challenge, Keithley Instruments (Cleveland, OH) has developed a switching array that maintains signal integrity from DC to microwave frequencies for evaluating and testing a multitude of RF devices, products, and systems.

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ROBERT GREEN
Product Marketing Managers,
Keithley Instruments, Inc.,
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OH 44139; (440) 248-0400,
FAX: (440) 248-6168, Internet:
www.keithley.com

The S46 Microwave Switch targets design evaluation, production testing, and environmental testing for cellular phones, pagers, base stations, personal digital assistants (PDAs), Web-enabled handsets, cordless phones, wireless-computing (Bluetooth) peripherals, broadband wireless-communication transceivers, RF integrated circuits (RF ICs) and other RF components, wideband circuits, subsystems, instruments, and high-speed digital circuits. The standard S46 system is specified for a bandwidth of 18 GHz, while custom systems can support bandwidths up to 40 GHz. Typical VSWR is 1.1:1 from DC to 15 GHz. Typical insertion loss is 0.5 dB at 5 GHz and 1.0 dB at 15 GHz.

The S46 has up to 32 channels to facilitate the configuration of numerous standard or fully custom systems for controlling microwave relays, programmable attenuators, and other types of active and passive RF components. The actual complement of relays (or other controllable channel devices) is specified by the user at the time of order, permitting the basic S46 mainframe to be used in a variety of multiplexers, matrices, independent relays, or combinations of configurations. Matrix configurations can be as large as a 2 × 6 nonblocking matrix or a 12 × 12 blocking matrix. An IEEE-488 interface simplifies the creation of programmable systems with other IEEE-488 instruments. The S46's

Continued on page 139

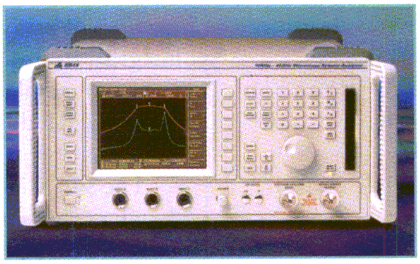
Group-Delay Option Enhances Microwave Analyzer

The addition of a group-delay module to this microwave analyzer helps engineers track amplitude and phase response in high-bandwidth applications to 46 GHz.

DON KELLER
Senior Editor

Conveying information without distorting it is essential to any communications link or signal-processing device. To achieve this, the link or device requires a flat amplitude response and a linear phase response over the bandwidth of interest. Phase linearity is commonly specified in terms of group-delay flatness. Traditionally, VNAs and spectrum analyzers have been used to perform group-delay measurements. But VNAs are complex, costly, and require highly skilled operators, limiting their usefulness. And spectrum analyzers require a separate synthesized source to perform converter measurements, making frequency sweeps difficult to control. However, a few present-day microwave system analyzers, such as the model 6845 from IFR (Wichita, KS), offer a group-delay option to simplify the process of performing such measurements **(see figure)**.

IFR's group-delay module plugs into an expansion slot inside the instrument, providing group-delay measurements and frequency modulation for microwave test applications to 46 GHz. Designed for engineers who manufacture, install, and maintain radio and satellite links and microwave systems, it supports simultaneous measurement and display of group delay and amplitude response. Group-delay range is from 1 ns to 10 μs with a resolution of 0.1 ns. A sophisticated marker system enables measurement of peak-to-peak ripple, and the group-delay characteristic's deviation from linear and from parabolic measurements in any operator-specified sub-band within the passband can be displayed as maximum peak-to-peak ripple in amplitude and group-delay, maximum slope, and maximum rate of change of the slope. During comparative peak-to-peak measurements, the accuracy is generally greater than 0.1 ns. The group-delay module also provides frequency modulation of the source from 0.1 Hz to 500 kHz. **IFR, 10200 West York St., Wichita, KS 67215-8999; (316) 522-4981, Internet: www.ifrsys.com.** MRF



The group-delay option allows the model 6845 microwave analyzer to measure and display group delay to 46 GHz.

Enter No. 58 at www.mwrf.com

Silicon MMIC Amplifier Boasts Low Noise Figure

This two-stage amplifier is a cost-effective solution for Rx front ends requiring moderate linearity in GSM, DCS-1800, and PCS-1900 applications up to 2 GHz.

C. LIN
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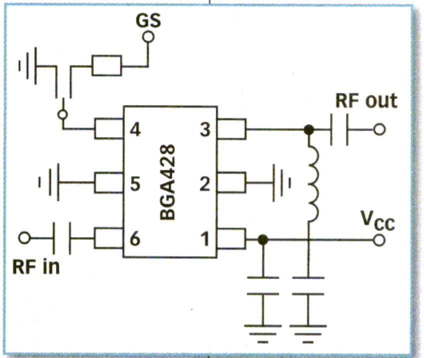
GLENN HOWARD
Agilent Technologies, 5301 Stevens Creek Blvd., Santa Clara, CA 95052

Receivers (Rxs) in wireless handsets must frequently detect signals at very low levels, which challenges designers to improve their noise performance. The BGA428 two-stage monolithic amplifier from Infineon Technologies (Munich, Germany) provides a firm foundation for low-noise Rx designs, with outstanding gain and noise-figure performance through 2 GHz. The BGA428 low-noise amplifier (LNA) features noise figure of 1.4 dB and gain of 20 dB at 1.8 GHz **(see table)**. It consumes only 8 mA at +2.4 to +3.0 VDC while achieving those performance levels. The noise performance of the BGA428 is believed to be the best yet achieved for a commercially available silicon (Si) bipolar-based monolithic-microwave-integrated-circuit (MMIC) LNA.

The BGA428 is based on Infineon's $\text{B6HF}_{\text{PLUS}}$ SIEGET 45 process, and is housed in a six-lead SOT-363 surface-mount package. The design was optimized to provide designers with the ability to produce a low-parts-count RF matching solution that requires only two external passive devices and blocking capacitors **(Fig. 1)**.



1. This simple circuit requires few external components.

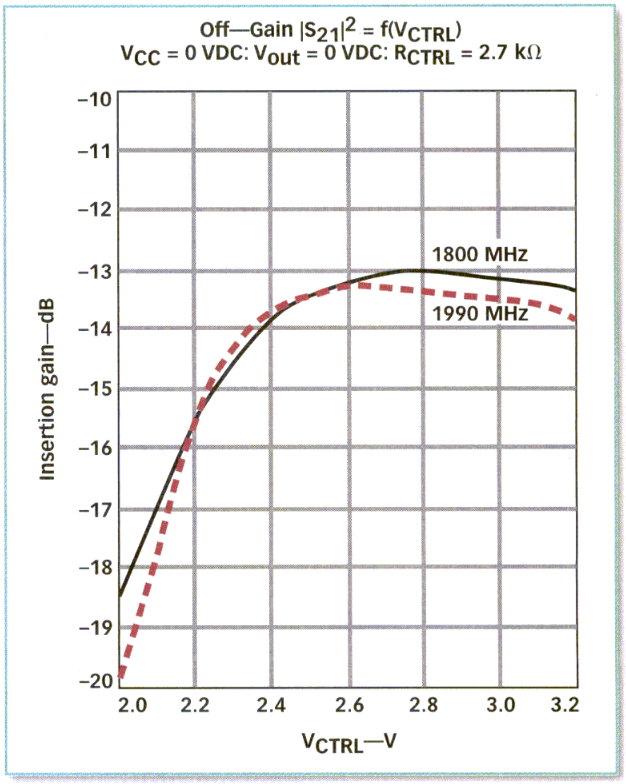
An integrated gain-step function allows gain to be adjusted by approximately 35 dB from 20 dB down to −15 dB in one step when the gain-step voltage is increased to +2.7 VDC, and the common-collector-voltage (V_{CC}), as well as the RF output (RF_{OUT}) pins, are DC-grounded or left in a floating-ground condition. Gain step is a necessary feature since the 20-dB gain of the BGA428 required for operation when receive signals are weak would cause distortion in the RF path when signals are strong. The options for implementing gain-step control typically require either an external switch to reduce gain to 0 dB, or to turn off the amplifier entirely.

The first option requires the undesirable use of external components, and the second reduces gain so dramatically that the Rx may no longer be able to detect the signal, resulting in a dropped call. The BGA428 provides the option of reducing gain to an intermediate level (−15 dB), delivering full gain (+20 dB), and reducing gain to −25 dB by removing power. Together, these three options provide the designer with more flexibility to handle changing signal condi-

Continued on page 132

The BGA428 at a glance (at 1.8 GHz)

Parameter	Specification
Power gain	20 dB
Noise figure (Z_s = 50Ω)	1.4 dB
Maximum input power	8 dBm
Input third-order intercept point	-9 dBm
Total current consumption	8.2 mA
Insertion loss in gain-step-mode (V_{CC} = 0 VDC, V_{GS} = + 27 VDC, R_{GS} = 3kΩ)	61
Dynamic gain range	35 dB



2. Off-mode gain performance is retained when using the base-collector diode to bypass the RF signal.

Continued from page 131

tions.

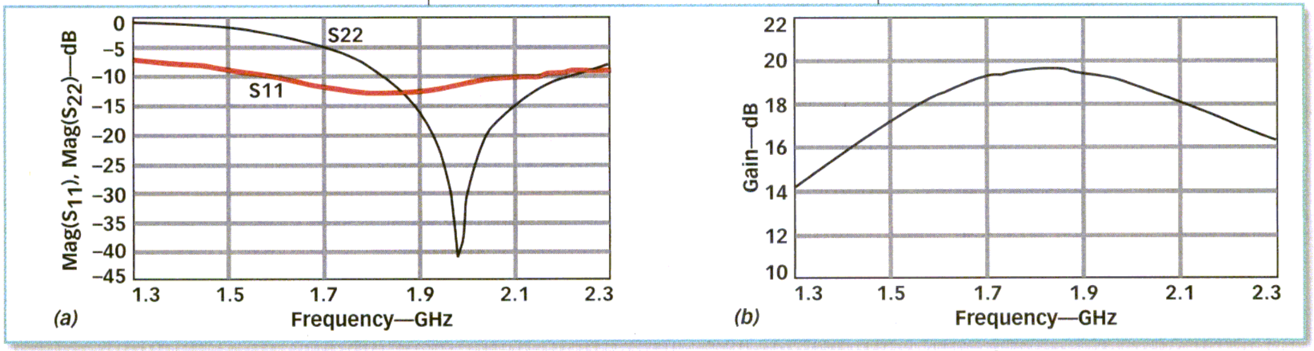
The BGA428 reduces circuit loss when V_{CC} is turned off (either V_{CC} and V_{OUT} are equal to 0 VDC, or V_{CC} and V_{OUT} are equal to a high impedance). This mode is enabled by switching the gain-step pin to a voltage of +2.7 VDC through an external resistor. The base-collector junction is forward biased, and its junction capacitance increases and resistance decreases, bypassing the RF signal to the RF output. This causes a low-impedance RF path from base to collector. The resulting off-mode gain for the BGA428 is shown in **Fig. 2.**

Modifying device input and output matching, noise matching, stability, and linearity is commonly achieved by intentionally inserting additional inductance (or resistance) between device emitter connections and RF ground. Although inductive degeneration does not seriously impact noise-figure performance (as resistive degeneration does), it must be realized by using bondwire or Spiral Inductors On Silicon (SIOS), and results in some uncertainty in length. In contrast, resistive degeneration requires large chip area and results in low-circuit quality factor (Q). On-chip prematching is desirable to counteract the effects of both techniques.

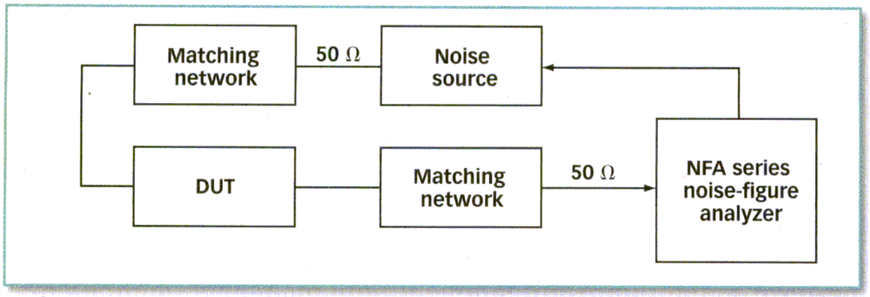
Since the BGA428 employs a two-stage, common-emitter amplifier followed by a degenerated open-collector, common-emitter stage, it is possible to tune the matching condition between the first and second stages using interstage tuning. This allows prematching to be achieved while maintaining low noise figure. The technique makes use of the non-vanishing reverse isolation (S_{12}) of the first stage, which increases with the size of emitter area. This increase, in turn, improves the noise figure since the resulting base resistance is lower.

By providing the proper load impedance, a good input match can be achieved without using additional elements at the input. In the BGA428, interstage tuning provides the required load at the expense of power matching. However, by properly scaling the current and area of the two transistors, and by defining an appropriate interstage match, Infineon produced a good compromise between noise figure, gain, and matching. The resulting input match and gain for the BGA428 are shown in **Fig. 3.** Good input match is achieved over a wide frequency range, and despite the interstage mismatch, the circuit still provides high gain.

Noise figure is an excellent way to characterize an entire system, as well as



3. Input matching is achieved over a wide frequency range, and gain remains greater than 18 dB from 1.6 to 2.1 GHz.



4. The test setup using the NFA series noise-figure analyzer has the performance required to measure the low noise figure of the BGA428.

its component parts, such as the preamplifier, mixer, and intermediate-frequency (IF) amplifier. The low noise figure achieved by the BGA428 requires a test setup with excellent noise performance, as well as the ability to deliver repeatable, accurate results without operator intervention and calculations. The noise-measurement system created to evaluate this device **(Fig. 4)** is built around the NFA series noise-figure analyzer from Agilent Technologies (Santa Clara, CA). This instrument provides simultaneous noise-figure and gain measurement in graphical format, as well as internal data storage. Use of the instrument was necessary due to its very low levels of uncertainty, which produces higher accuracy and increased measurement reliability. Without the noise-figure analyzer, it would have been difficult to find an affordable way of performing meaningful measurements at such low levels of noise figure.

The common-emitter measurement mode, where a calibrated noise source is connected to the base of the device, was chosen for the measurements. Tunable input/output (I/O) matching networks enable evaluation of the noise figure at the matched condition with minimal uncertainty. The analyzer is first configured for the correct frequency sweep and calibrated by feeding the noise-source signal directly into the instrument and then measuring the noise figure of the analyzer at various attenuator settings. The test setup allows the matching network to be fully characterized, including frequency-dependent loss compensation before and after the device under test (DUT).

The BGA428 is available on tape and reel for manufacturing. P&A: $0.36 (100,000 qty.). **Infineon Technologies, Silicon Discrete Group, Balanstrasse 73, D-81541-Munich, Germany, Internet: www.infineon.com.** MRF

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GE Corporate Research and Development has an exciting position available for a Microwave/Millimeter Wave R&D Engineer. The right individual will be able to invent leading edge solutions for communications and radar systems. This position requires a Ph.D. degree, or M.S. degree with two years' experience. Qualified candidates should have a proven record of developing advanced technologies as well as project leadership and communication skills. **Job Code: CRD/252304/AN00.**

Other Requirements: Must be able to design microwave/millimeter wave hybrid circuits. Must be able to design microstrip line filters, circulators, and other transmission line elements. Must be able to use CAD tools such as HFSS, SONNET, and MENTOR. Must be able to test microwave circuits and use network analyzers, vector impedance meters, and other equipment. Must have a record of innovation demonstrated by published technical papers and/or patents.

This position requires US Citizenship or permanent US residency; if you do not meet this please do not apply.

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How to apply: For confidential consideration, please send an e-mail with the text of your resume to: **opportunities@gecareers.com** Please reference the Job Code (located at the end of each job description) in the subject line of your e-mail. You may also mail your resume, referencing the job code, to our processing center at: **GE Resume Processing, 37 Whitcomb St., Waltham, MA 02453.** An equal opportunity employer.

GE Corporate Research & Development Center

www.crd.ge.com

Inductors Range From DC To 800 MHz

THE MODEL 7000 coaxial relay model features 2 to 24 throws, with a frequency range of DC to 800 MHz depending on the number of throws. Switchpoints are individually field replaceable and signal circuits are isolated from control circuitry. Built-in amplifiers are available for video and RF applications. Matrix and hybrid systems are constructed by using 9000-series push-on cross straps which mate with BNC connectors on the switch module. Typical applications include RF and intermediate-frequency (IF) switching, baseband video and pulse switching, and switching balanced audio.

Matrix Systems, 5177 Douglas Fir Rd., Calabasas, CA 91302; (818) 222-2301, FAX: (818) 222-2304, e-mail: tech@matrixsystems.com, Internet: www.matrixsystems.com.

● Enter No. 83 at www.mwrf.com

Isolators Work To 40 GHz

A LINE OF single- and dual-junction coaxial isolators and circulators covers standard bands in narrowband, octave, and multioctave frequency ranges up to 40 GHz. Waveguide isolators and circulators cover 12.4 to 18.0 GHz (WR62) and 18.0 to 26.5 GHz (WR42) in 10-percent bandwidths. Isolated waveguide flanges in 200-MHz bandwidths, as well as ISO-guide waveguide to coaxial adapters including integral isolators can be supplied. The model M3I2640 covers the 26.5-to-40.0-GHz frequency range with a typical isolation of 15 dB and an insertion loss of 0.8 dB, while the M3I5964 spans 5.9 to 6.4 GHz with an isolation of 26 dB typical, an insertion loss of 0.1 dB, and a VSWR of 1.10:1. Coaxial units are supplied with nickel (Ni)-plated housings and a chemical-film finish per MIL-C-5541B Class 3.

Midisco, 1707 Veterans Memorial Highway, Unit 32, Islandia, NY 11749-1581; (800) 637-4353, (631) 234-3505, FAX: (631) 234-3913, Interent: www.microwavedistributors.com/midisco.

● Enter No. 84 at www.mwrf.com

Detectors Cover 10 MHz to 40 GHz

THE MODEL 603SK planar-doped barrier detector spans 10 MHz to 40 GHz. The unit is available with an input connector of 3.5 mm, 2.4 mm, or K male. Frequency response is ±0.3 dB to 20 GHz, ±0.6 dB to 26.5 GHz, and ±1 dB to 40 GHz. Maximum VSWR is 1.3 to 20 GHz, 1.4 to 26.5 GHz, and 1.5 to 40 GHz. With a low-level sensitivity of 0.4 mV/μW minimum, video impedance is 0.8 to 3.0 kΩ. P&A: stock to 6 wks.

Krytar, 1292 Anvilwood Ct., Sunnyvale, CA 94089; (408) 734-5999, FAX: (408) 734-3017, Internet: www.krytar.com.

● Enter No. 85 at www.mwrf.com

PA Operates From 290 To 320 MHz

THE MODEL A020 is a Class AB high-performance power amplifier (PA) covering the 290-to-320-MHz frequency range. Output power is 120 W CW typical, gain is 35 dB typical, efficiency is 55 percent, and DC power is +28 VDC. Connectors are surface-mount architecture (SMA) female. Automatic current limiting, forced air cooling, current meter, and overcurrent and thermal protection are offered. The high-performance PA is housed in a 4.8 × 2.0 × 1.0-in. (12.19 × 5.08 × 2.54-cm), 1-lb. package.

LCF Enterprises, 570 W. Clearwater Loop, Bldg. A, Post Falls, ID 83854; (208) 457-0292, FAX: (208) 457-0296, e-mail: info@lcfamps.com, Internet: www.lcfamps.com.

● Enter No. 86 at www.mwrf.com

TCXO Spans 10 To 20 MHz

THE FOX801BE SERIES of temperature-controlled crystal oscillators (TCXOs) displays an inclusive frequency stability of ±2.5 PPM over a frequency range of 10 to 22 MHz. Operating temperature range is −30 to +75°C, with a choice of +3 or +5 VDC. An optional trimmer supports frequency adjustments of ±3 PPM, while an optional voltage control creates a VCTCXO with a range of either ±5 or ±8 PPM. Available frequencies include 10.0, 12.8, 14.4, 16.0, 19.2, and 20.0 MHz. P&A: less than $5.00 ea. (10,000 qty.); stock.

Fox Electronics, 5570 Enterprise Parkway, Fort Myers, FL 33905; (888) GET-2-FOX, FAX: (941) 693-1554, e-mail: sales@foxonline.com, Internet: www.foxonline.com.

● Enter No. 87 at www.mwrf.com

Chokes Reduce EMI

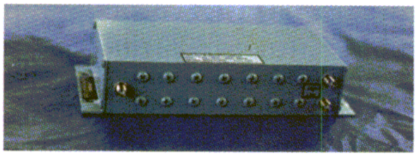
THE 1110, 1120, 1130, and 1140 series of RF chokes are designed to reduce electromagnetic interference (EMI). Inductance range is 1 to 15,000 μH, operating temperature range is −55 to +105°C, and dielectric voltage strength is +2500 VDC root mean square (RMS). The chokes are manufactured with an epoxy-coated ferrite bobbin core with VW-1-rated shrink tubing to cover the winding. The devices are self-leaded and feature fixed lead spacing. P&A: $2.00 to $7.28 each (250 qty.).

J.W. Miller Magnetics, 306 E. Alondra Blvd., P.O. Box 2859, Gardenia, CA 90247; (310) 515-1720, FAX: (310) 515-1962, Internet: www.jwmiller.com.

● Enter No. 88 at www.mwrf.com

Diplexers Cover GSM Band

THE VAD SERIES of high-performance compact diplexers is suitable for use in the specialized-mobile-radio (SMR), Cellular A and B, Advanced Mobile Phone Service (AMPS) A and B, third-generation (3G), and Global System for Mobile Communications (GSM) bands. Using patented technology, these diplexers have temperature stability ranging from −40 to +75°C. Applications include repeaters and range extenders. The unit is housed in a 3.0 × 6.0 × 1.4-in. (7.62 × 15.24 × 3.56-cm) package and features SMA connectors. P&A: $140.00 each (1 to 9 qty.).



Wireless Technologies Corp., P.O. Box 7033, Springdale, AR 72762; (501) 750-1046, FAX: (501) 750-4657, e-mail: wireless@ipa.net, Internet: www.duplexers.com.

● **Enter No. 89 at www.mwrf.com**

Connectors Work Up To 18 GHz

THE TNC SERIES of coaxial connectors features a frequency range that has been extended to 18 GHz by modifying their interface dimensions, while conforming to MIL-C-39012 interface standards. Constructed of brass outer shells with silver (Ag), nickel (Ni), or Trulustre plating or from stainless steel, gold (Au)-plated beryllium-copper (BeCu) center conductors, and Teflon® insulators, the connectors can be attached to cables by crimp, standard, and conical taper clamps. Applications include military, aviation, and telecommunications. P&A: $9.95 each.

Tru-Connector Corp., 245 Lynnfield St., Peabody, MA 01960-5094; (800) COAX-TRU, (978) 532-0775, FAX: (978) 531-6993, e-mail: trusales@tru-con.com, Internet: www.tru-con.com.

● **Enter No. 90 at www.mwrf.com**

SSPAs Support L-Band Input Operations

A SERIES OF compact outdoor solid-state power amplifiers (SSPAs) for satellite-communications applications is available in power levels ranging from 10 to 70 W at Ku-band frequencies and from 30 to 200 W at C-band. Extended frequency-band operation and L-band input operations are supported. The amplifiers can be mounted on an antenna strut, a pedestal, or inside a hub.

Paradise Datacom LLC, 1012 E. Boal Ave., Boalsburg, PA 16827; (814) 466-6275, FAX: (814) 466-3341, e-mail: sales@paradisedata.com, Internet: www.paradise.co.uk.

● **Enter No. 91 at www.mwrf.com**

Gaskets Feature Conductive Traces

MICROSCOPIC CONDUCTIVE TRACES are co-extruded through the interior sponge core of the Microbridge® RF-interference (RFI) shielding gaskets, placing the conductors only where they are needed. The result is an RFI shielding gasket that retains all of the pure silicon (Si) substrate characteristics without compromising the physical properties of low-compression force, resiliency, tear resistance, tensile force, and long-life aging.

Vanguard Products Corp., 87 Newtown Rd., Danbury, CT 06810; (203) 744-7265, FAX: (203) 798-2351, e-mail: vanguard@worldnet.att.net, Internet: www.vanguardproducts.com.

● **Enter No. 92 at www.mwrf.com**

Oscillators Operate To 60 MHz

THE MODEL VPC1 programmable crystal-controlled oscillators are housed in an industry-standard 5 × 7-mm ceramic surface-mount package and have a frequency range up to 60 MHz. The units are high-performance complementary metal-oxide semiconductor (HCMOS) or TTL compatible and available with either a supply voltage of +5.0 VDC ±10 percent or +3.3 VDC ±10 percent. Operating temperatures are 0 to +70°C or −40 to +85°C. Options include ±25-, ±50-, or ±100-PPM frequency stabilities and a tristate or power-down function. P&A: $2.05 (1000 qty.) for the metal can and plastic-package units and $2.16 (1000 qty.) for the VPCI; 2 days.

VITE Technology Express, 166 Glover Ave., P.O. Box 5160-5160, Norwalk, CT 06856; (203) 853-4433, FAX: (203) 849-1423, Internet: www.viteonline.com/products/index.htm

● **Enter No. 93 at www.mwrf.com**

Antenna Feed Offers 6-dBi Gain

THE MODEL 0027 is a prime-focus, S-band, dual-circular-polarized antenna feed that is environmentally sealed with a radome and gaskets. Frequency range is 2.332 to 2.345 GHz with a gain of 6 dBi. With an isolation of 30 dB minimum and a VSWR of 1.5:1 maximum, the temperature range is −50 to +52°C.

Seavey Engineering Associates, Inc., 28 Riverside Dr., Pembroke, MA 02359; (781) 829-4740, FAX: (781) 829-4590, Internet: www.seaveyantenna.com.

● **Enter No. 94 at www.mwrf.com**

Relay Targets Test Equipment

THE MW6 IS a microwave frequency relay that provides signal isolation at 6 GHz of 18 dB. Insertion loss is 0.38 dB and VSWR is 1.30:1. Coil-input voltages of +5.0, +12.0, +18.0, and +26.5 VDC are available. The MW6 relay offers a printed-circuit-board (PCB) footprint of 0.108 in.^{2} and is 0.280 in.^{2} high. Applications include precision test equipment and communications systems. P&A: $50.00 to $60.00 each.

CII Technologies, Inc., 1200 Ridgefield Blvd., Suite 200, Asheville, NC 28806; (828) 670-5300, FAX: (828) 670-6132, Internet: www.ciitech.com.

● **Enter No. 95 at www.mwrf.com**

Diplexer Offers 60-MHz UMTS/DCS Bandwidth

THE MINIATURE INTERMODULATION-distortion (IMD)-free W2446D diplexer is designed for video reception and transmission applications in the Universal Mobile Telecommunications System (UMTS)/digital-communications-services (DCS) band. With an operating temperature that spans the −40 to +70°C range, standard +43-dBm input test signals produce less than −100 dBm of IMD signals. Bandwidth spans across the 2110-to-2170-MHz frequency range, while insertion loss is rated at less than 1 dB with a return loss that is better than −17 dB. Transmitter (Tx)-to-receiver (Rx) isolation is greater than 65 dB. Power handling is greater than 100 W continuous wave (CW) and peak power rating is greater than 1.5 kw. P&A: less than $150.00.

Wireless Technologies Corp., P.O. Box 7033, Springdale, AR 72762; (877) 420-7983, (501) 750-1046, FAX: (501) 750-4657, e-mail: wireless@ipa.net, Internet: www.duplexers.com.

● **Enter No. 96 at www.mwrf.com**

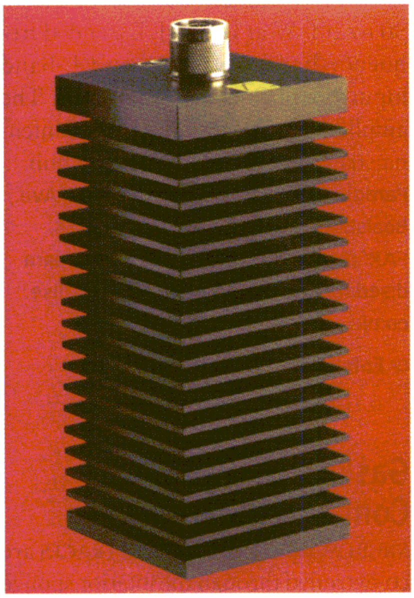
Connectors Are Suitable For Cellular Devices

TWO APPLICATION CONNECTORS are designed for use in cellular device applications where board and chassis space are limited. These right-angle connectors mate with printed-circuit-board (PCB) and card-mounted jacks. The RMC-6010-A connector is available for RG-178-U cable while the RMC-6010-B is designed for use with RG-174/U, RG-188/U, along with RG-316/U cables. The connector bodies are comprised of nickel (Ni)-plated and machined brass. The connector contacts consist of gold (Au)-plated beryllium copper (BeCu) with the insulation being Teflon.

RF Connectors, 7610 Miramar Rd., San Diego, CA 92126; (858) 549-6340, FAX: (858) 549-6345, e-mail: rfi@rfindustries.com, Internet: www.rfindustries.com.

● **Enter NO. 97 at www.mwrf.com**

Termination Spans DC To 3 GHz



THE MODEL 100 NST-FN is a termination that uses aluminum-nitride (AlN) as an alternative to beryllium-oxide (BeO) substrates. Covering DC to 3 GHz, VSWR is 1.1:1 maximum at DC to 1 GHz and 1.15:1 maximum at 1 to 3 GHz. The power rating is 100 W average. BNC, N, TNC, and 7/16 connectors are available.

Bird Component Products, 10950 72nd St. N., Suite 107, Largo, FL 33777; (727) 547-8826, FAX: (727) 547-0806, e-mail: sales@birdfla.com, Internet: www.birdfla.com.

● **Enter No. 98 at www.mwrf.com**

Epoxy Delivers 2400-psi Lap Shear

THE PF2010 IS a silver (Ag)-filled unsupported epoxy adhesive film that provides very thin, uniform bond lines and combines electrical and thermal conductivity. Typical properties include an aluminum-to-aluminum (Al-to-Al) lap shear of more than 2400 psi, thermal conductivity at 121°C of 3.5 W/m°K, and volume resistivity of 0.0002 Ω-cm. It has a room-temperature work life of 90 days and a long shelf life when store frozen. The epoxy is available in sheet, tape, or die-cut pieces for specific bond lines.

National Starch and Chemical Co., 10 Finderne Ave., P.O. Box 6500, Bridgewater, NJ 08807; (978) 436-9850, e-mail: CAD@preformadhesives.com.

● **Enter No. 99 at www.mwrf.com**

Test Kit Covers 40 To 220 GHz

THE FCC SPURIOUS and Harmonic Test Kit are designed for use with popular spectrum analyzers. Each kit contains four mixers, providing continuous coverage from 40 to 220 GHz. Each mixer is equipped with an appropriate horn antenna for accomplishing the Federal Communications Commission (FCC)-desired rated spurious-level measurement.

Oleson Microwave Labs, 355 Woodview Dr., Suite 300, Morgan Hill, CA 95037; (408) 779-2698, FAX: (408) 778-0491, Internet: www.oml-mmw.com.

● **Enter No. 100 at www.mwrf.com**

Converter Accepts 160-MHz IF Signals

THE CS-1024G IS a dual-channel, intermediate-frequency (IF)-to-baseband converter that accepts IF input signals at 70 MHz, 140 MHz, or 160 MHz and converts those signals to a baseband output. The unit features matched-gain and phase characteristics between its dual channels. This instrument, combined with the CS-5038 Dual Channel Microwave Receiver (Rx), can produce matched-path characteristics over the entire receiving signal path, from the microwave antenna-signal input to the baseband output where the signals can then be digitized and processed. The converter can handle signal bandwidths between 250 kHz and 80 MHz and has greater than 60 dB of gain control. A trigger option is included.

Communication Solutions, Inc., 10552 Philadelphia Rd., P.O. Box 43550, Baltimore, MD 21236; (410) 344-9000, FAX: (410) 344-1790, e-mail: sales@comsolinc.com, Internet: www.comsol-inc.com.

● **Enter No. 101 at www.mwrf.com**

Continued from page 116

cdma2000, wideband CDMA (WCDMA), and Enhanced Data-rates-for-Global-Evaluation (EDGE) standards. The signal generators feature level accuracy of better than ±0.5 dB for output levels above −127 dBm and frequencies below 2 GHz.

The company's latest line of synthesized signal generators, the Performance Signal Generator (PSG) series, provide frequency coverage as wide as 250 kHz to 40 GHz with low phase noise, 0.01-Hz frequency resolution, and high output power for a wide range of broadband commercial and military measurement applications **(Fig. 2)**. The PSG sources are code compatible with the earlier 8360 and 8370 signal generators to simplify installation in automatic-test-equipment (ATE) systems. The front panels of the PSG sources are clean and straightforward, resembling the firm's ESG digital signal-generator line.

Aeroflex Comstron *and Programmed Test Sources offer high-speed solutions suitable for RF testing.*

The PSG line includes the 250-kHz-to-20-GHz models E8241A and 8251A and the 250-kHz-to-40-GHz models E8244A and E8254A. The E8241A and E8244A are meant for use as calibrated local oscillators (LOs) and do not include modulation, while the E8251A and E8254A provide AM, FM, phase modulation, as well as pulse modulation.

The PSG sources achieve low phase noise of −110 dBc/Hz offset 20 kHz from a 10-GHz carrier. Through option UNJ, the phase noise can be improved close to the carrier to −104 dBc/Hz offset 500 Hz from a 10-GHz carrier. The low phase noise is based on the use of a precise oven-controlled crystal oscillator (OCXO) in both cases.

Both 20-GHz models feature an output power range of −20 to +13 dBm from 250 kHz to 20 GHz, with higher output levels available through an option. The 40-GHz models offer output-power levels of −20 to +10 dBm across the full 250-kHz-to-40-GHz range, also with an option for higher output power. For power levels greater than +10 dBm, the level accuracy is ±1.3 dB from 250 kHz to 20 GHz. For power levels of −10 to +10 dBm, the level accuracy is better than ±0.9 dB from 250 kHz to 40 GHz. Power levels in the PSG synthesizers can be adjusted with 0.01-dB resolution.

Another major supplier of high-quality signal sources, Rohde & Schwarz (Munich, Germany) offers the SME an SMR lines of analog signal generators for RF and microwave applications, respectively. The SME line includes the 5.0-kHz-to-1.5-GHz model SME 02, the 5-kHz-to-3-GHz model SME03, the 5.0-kHz-to-2.2-GHz model SME03E, and the 5-kHz-to-6-GHz model SME06. The SMR series includes the 1-to-20-GHz model, the 1-to-27-GHz model SMR27, the 1-to-30-GHz model SMR30, and the 1-to-40-GHz model SMR40. All of the generators offer an option for coverage to 10 MHz. The source provides +10-dBm leveled output power to 20 GHz and +9-dBm leveled output power to 40 GHz, with amplitude coverage as low as −130 dBm through an optional step attenuator.

The company's SMIG line of vector signal generators addresses the requirements of testing with digitally modulated signals. The line includes the 300-kHz-to-2.2-GHz model SMIQ02B, the 300-kHz-to-3.3-GHz model SMIQ03B, the 0.3-to-4.4-GHz model SMIQ04B, as well as the 0.3-to-6.4-GHz model SMIQ06B. All of these sources offer 0.1-Hz frequency resolution and output levels from −140 to +13 dBm that can be set with 0.1-dB resolution. The phase noise for the 02B and 03B models is less than −126 dBc/Hz offset 20 kHz from a 1-GHz carrier. In addition to conventional analog modulation, the generators incorporate an extremely broadband 30-MHz vector modulator for creating the complex modulation formats common to modern communications systems.

For multi-tone testing, the MTG 2000 multi-tone signal generator from Aeroflex RDL (Conshohocken, PA) can provide up to 16 independent CW signals for testing multi-tone cellular power amplifiers (PAs). Each tone is generated by a separate source with 10-Hz frequency resolution, with frequency ranges of 800 to 1000 MHz and 1700 to 2200 MHz available for cellular and personal-communications-services (PCS) testing. The firm also offers the model CSG multicarrier signal generator for cable-television (CATV) testing. The CSG can be supplied with capability for generating up to 159 simultaneous tones.

For high-speed frequency switching, Aeroflex Comstron (Plainview, NY) and Programmed Test Sources (Littleton, MA) offer high-speed solutions for RF testing. The FastSource 1200 from Aeroflex Comstron operates from 4.5 to 6010 MHz with less than 100-µs switching speed to within 1 radian of the final phase/frequency. The phase noise is typically −110 dBc/Hz offset 1 kHz from the carrier and −125 dBc/Hz offset 10 kHz from the carrier. The synthesizer delivers +7-dBm output power with ±1.5-dB flatness across its frequency range. The frequency resolution is 1 Hz from 4.5 to 1999 MHz, 2 Hz from 2000 to 3999 MHz, and 4 Hz from 4000 to 6010 MHz. The firm also offers the rack-mount model FS-2000 synthesizers for applications through 18.4 GHz and the modular model FS-5000 synthesizer for use through 18 GHz, the latter with better than 200-ns switching speed.

The PTS 3200 frequency synthesizer from Programmed Test Sources provides frequency coverage from 1 to 3200 MHz with switching speeds in excess of 20 µs. The source provides output levels to +13 dBm with ±0.7-dB flatness, as well as 1-Hz frequency resolution. The phase noise is less than −116 dBc/Hz offset 10 kHz from the carrier, with a noise floor of −130 dBc/Hz. The firm also manufactures the model PTS 1000 for applications from 0.1 to 1000 MHz.

Epoxy Preforms

A BROCHURE CONTAINS an overview of standard and custom epoxy preform applications. A description of the advantages of epoxy preforms compared to traditional liquid dispensing systems is provided. Product specifications, as well as an introduction to automatic, semi-automatic, and manual-loading systems are included.

Multi-Seals, Inc.; (860) 643-7188, FAX: (860) 643-5669, e-mail: sales@multi-seals.com, Internet: www.multi-seals.com.

● **Enter No. 60 at www.mwrf.com**

Conformal Encapsulants

A BROCHURE DESCRIBES a line of solvent-free, light-curing conformal coatings and encapsulants. The brochure features processing information, as well as a selector guide that lists five conformal coatings along with four encapsulants. Features, benefits, and agency approvals that differentiate the line from traditional, slower- curing conformal coatings are provided.

Conformal Coatings and Encapsulants

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Solvent-Free Resins matched to Dymax curing and dispensing systems for easy, fast automation

Dymax Corp., (877) 396-2988, (860) 482-1010, FAX: (860) 496-0608, e-mail: info@maxcorp.com, Internet: www.dymax.com.

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Heat Sinks

A 24-PAGE catalog offers extruded and special heat sinks. Specifications include dissipated power, thermal resistance, air-temperature rise, time constant, air-volume stream, fan-power input, fan-nominal voltage, speed, bearings, materials, finish, mounting surface, and weight with or without fans.

Alutronic Kuhlkorper GmbH & Co. KG; (0 23 53) 9 15-5, FAX: (0 23 53) 91 53 33, e-mail: alutronic@t-online.de, Internet: www.alutronic.de.

● **Enter No. 62 at www.mwrf.com**

Heat-Activated Adhesives

A CATALOG PROVIDES specifications, tape constructions, and suggested end uses for four classes of pressure-sensitive adhesives. Rubber-based (double-coated foams, single-coated foams, and double-coated films), acrylic-based (doubled-coated films, transfer adhesives, double-coated foams, and single-coated foils), silicone-based (double-coated films, transfer adhesives, and single-coated foils), and heat-activated adhesives are offered. Descriptions of the PSA-tape systems for industrial end-use markets are included.

Adhesives Research, Inc.; (717) 235-7979, (717) 235-8320, Internet: www.adhesivesresearch.com.

● **Enter No. 63 at www.mwrf.com**

Cable Assemblies

A SIX-PAGE brochure discusses design and manufacturing services for a range of custom cable assemblies, various types of battery packs and technologies, and interconnection components. Design- and reverse-engineering services, documentation preparation, component sourcing, manufacturing and testing, and vendor-managed inventory are covered.

Aved/Generation Electronics, Inc.; (800) 441-2833, (978) 453-6393, FAX: (978) 453-6470, e-mail: info@aved.com, Internet: www.aved.com.

● **Enter No. 64 at www.mwrf.com**

Oscillator Jitter

AN EIGHT-PAGE technical application note discusses the causes and consequences of oscillator jitter in wireless and data-communications circuits and systems. Twelve frequently-asked questions (FAQ), touching upon measurement, readability, rise time, as well as clock-waveform symmetry, are listed and answered. Technical drawings are included.

MF Electronics; (914) 712-2200, FAX: (914) 576-6204, e-mail: sales@mfelectronics.com, Internet: www.mfelectronics.com.

● **Enter No. 65 at www.mwrf.com**

Industrial Materials

A 24-PAGE brochure provides information on the capabilities of a company that supplies metals, polymers, ceramics, as well as other materials to meet the research, development, and specialist production requirements for scientific and industrial applications. Company structure and material availability are covered. A product guide is included.

Goodfellow Corp.; (800) 821-2870, (610) 640-1612, FAX: (800) 283-2020, (610) 993-8065, e-mail: info@goodfellow.com, Internet: www.goodfellow.com.

● **Enter No. 66 at www.mwrf.com**

Power Conversion

POWER-CONVERSION SYSTEMS are the subject of a 68-page catalog. DC-to-DC and AC-to-DC converters, DC-to-AC and AC-to-AC inverters, and battery chargers are offered. Mechanical specifications are included.

Schaefer, Inc.; (508) 881-7330, FAX: (508) 231-0861, e-mail: sales@schaeferpower.com, Internet: www.schaeferpower.com

● **Enter No. 67 at www.mwrf.com**

DAQ Systems

A CATALOG INCLUDES a selection of benchtop programmable function, pulse/function, and universal/arbitrary waveform generators. Counters and frequency standards; portable, networked, and wireless data-acquisition (DAQ) systems; and plug-and-play VXI products are presented.

Fluke Corp.; (888) 492-7554, FAX: (425) 446-5116, e-mail: fluke-info@fluke.com, Internet: www.calibration.fluke.com.

● **Enter No. 68 at www.mwrf.com**

LNBs/Tuners

A BROCHURE COVERS high-frequency products. Low-noise block downconverters (LNBs), tuners, modulators, and antenna units are offered. Specifications include supply voltage, current consumption, local-oscillator (LO) frequency, intermediate-frequency (IF) output, conversion gain, operating temperature, and operating voltage. Application information is presented.

Alps Electric Europa GmbH; (+49) 211/5977-0, FAX: (+49) 211/5977-146, e-mail: alpseuropa@alps-europe.com, Internet: www.alps-europe.com.

● **Enter No. 69 at www.mwrf.com**

Military Connectors

A 266-PAGE catalog offers solutions for connector needs regarding commercial, industrial, harsh-environment, as well as military applications. Comparison charts for 23 connector series, layouts, dimensions, and illustrations are included. Test data, technical specifications, selection guides, and assembly instructions are provided.

PEI-Genesis; (800) 773-3840, Internet: www.pei-genesis.com.

● **Enter No. 70 at www.mwrf.com**

Connectors/Cable

A 280-PAGE catalog features components and assemblies that are suitable for a variety of applications. Connectors, cable, integrated-circuit (IC) sockets, semiconductors, transistors, diodes, rectifiers, crystals, oscillators, inductors, coils, filters, capacitors, and resistors are specified. Potentiometers, thermistors, switches, relays, test equipment, batteries, fuses, transformers, and power supplies are also included.

Digi-Key Corp.; (800) 344-4539, (218) 681-6674, FAX: (218) 681-3380, Internet: www.digikey.com.

● **Enter No. 71 at www.mwrf.com**

Pick-And-Place System

A BROCHURE COVERS the general-purpose model 830 semiautomatic pick-and-place system for die- and surface-mount components. The system works with any tape-mounted die-removal system. Product features, including optional epoxy die-bonding capability, and specifications are offered.

Semiconductor Equipment Corp., (805) 529-2293, FAX: (805) 529-2193, Internet: www.semicorp.com.

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Technical Computing

THE MATLAB 6 Information Kit includes an overview of MATLAB, with technical data sheets and code examples. Information shows how MATLAB and its companion products can help users interface to external devices and data, perform complex analyses, visualize data, and develop algorithms and applications faster and more effectively.

The MathWorks; (508) 647-7000, FAX: (508) 647-7101, e-mail: info@mathworks.com, Internet: www.mathworks.com/mtlb6.

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Power Amplifiers

A BROCHURE DETAILS wireless communications products. Power amplifiers (PAs), local multipoint-distribution services (LMDS), point-to-multipoint amplifiers, very-small-aperture-terminal (VSAT)/satellite-communications (SATCOM) amplifiers, super-broadband amplifiers for fiber optics, high-power amplifiers, as well as up and downconverters are covered. Information that focuses on design, quality, and manufacturing is provided. Specifications are included.

CTT Wireless; (408) 988-2999, e-mail: wireless@cttinc.com.

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Continued from page 129

compact 2U [3.50-in. (8.89-cm)-high] form factor conserves rack space, and the physical layout of the front and/or rear panel can be designed to customer specifications.

Standard versions of the S46 can accommodate up to eight single-pole, double-throw (SPDT) coaxial microwave relays and four multipole coaxial microwave relays. Any of the four multipole coaxial relays can be single-pole, three throw (SP3T); single-pole, four throw (SP4T); single-pole, five throw (SP5T); or single-pole, six throw (SP6T). Relays can be added to the system as test requirements evolve. The modular nature of the S46 minimizes the number of subassemblies in the system, resulting in easier system specification at the time of order.

A contact-closure counter in the S46 allows users to monitor the remaining service life of relays. Relays are rated for a minimum of two million cycles, and the system counts and stores the number of contact closures for each relay in nonvolatile memory. These data enable maintenance to be scheduled proactively when relays are nearing the end of their mechanical life, rather than in response to unexpected failures that can result in lost production time. In addition to counter data, the S46's nonvolatile memory can store up to 68 B of parameter information for each relay contact or pathway. If a specific performance parameter is critical, such as VSWR or insertion loss, the parameter can be stored in memory for trend analysis between scheduled maintenance shutdowns.

Other sourcing, switching, and measurement instruments for use with the S46 are also available from the manufacturer. This allows the user to specify and obtain complete test solutions where instruments share common programming requirements, and can be supported by a single, comprehensive product-service-and-support organization. **Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, OH 44139; (440) 248-0400, FAX: (440) 248-6168, Internet: www.keithley.com** MRF

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GPS Networking

A 40-PAGE catalog offers books and software covering communications engineering and management. Subjects such as wireless third generation (3G), general-packet radio service (GPRS), Global System for Mobile Communications (GSM), satellite communications, intelligent transportation systems (ITS), and Global Positioning System (GPS), networking, Internet, security, and e-commerce are detailed. Software engineering and computing are also presented.
Artech House; (800) 225-9977, (781) 769-9750, FAX: (781) 769-6334, e-mail: artech@artechhouse.com, Internet: www.artechhouse.com.

● **Enter No. 75 at www.mwrf.com**

Coaxial Cables

A 10-PAGE selector guide includes coaxial cables with single, double, and triple shielding. These cables are suitable for communications infrastructure as well as test and measurement, where performance and repeatability are required. Cables with stainless-steel armor are offered, along with such options as removable connector heads.
Avnet; (800) 778-4401, (480) 985-9000, FAX: (480) 985-0334, Internet: www.semflex.com.

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Power Amplifiers

AN 18-PAGE catalog features analog-design solutions. Low-noise amplifiers (LNAs), power amplifiers (PAs), voltage-controlled oscillators (VCOs), mixers, upconverters, downconverters, driver integrated circuits (ICs), as well as receivers (Rxs) are examined. Modulators, demodulators, transceivers, transmitters (Txs), buffer amplifiers, data converters, power controls, and power supplies are offered. Specifications, such as supply voltage, resolution, input channels, sample rate, voltage reference, data-bus interface, output power, and power control, are included.
Maxim Integrated Products, Inc.; (800) 998-8800, (408) 737-7600, FAX: (408) 737-7194.

● **Enter No. 77 at www.mwrf.com**

DAQ Recorder

A 12-PAGE brochure describes the compact, high-speed Dash 18™ "One Touch" data-acquisition (DAQ) recorder. The brochure contains complete specifications of the unit and a variety of close-up photos of the monitor in various configurations. The brochure also provides unretouched chart samples from the optional printer, as well as other options such as microphones and webcams.
Astro-Med, Inc.; (877) 867-9783, e-mail: MTGroup@astromed.com, Internet: www.astro-med.com.

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Input/Outputs

A 32-PAGE catalog focuses on personal-computer (PC)-based analog input/outputs (I/Os). Ultra-high-speed PC-interface (PCI)-bus-compatible four-channel 12-b analog input boards; ultra-high-speed PCI-bus-compatible 14-b, 64-channel analog input boards; and ultra-high-speed PCI-bus-compatible 16-b, 64-channel analog input boards; PCI-bus-compatible analog I/O boards; and ultra-high-speed four-channel, 12-b analog input boards are specified. ISA-bus-compatible analog I/Os and counter/timer boards and PC-card-compatible analog I/O and counter/timer boards are also available.
Measurement Computing; (508) 946-5100, FAX: (508) 946-9500, Internet: www.MeasurementComputing.com.

● **Enter No. 79 at www.mwrf.com**

Resistance Testers

A FOUR-PAGE brochure highlights the 3711 and 3731 models of clamp-on ground-resistance testers. Product descriptions, features, constructions, and functions are covered. Specifications, such as resistance and current measurement frequencies, current overload, power supply, battery life, operating humidity, and operating temperature, are provided.
AEMC Instruments; (800) 343-1391, (508) 698-2115, FAX: (508) 698-2118, Internet: www.aemc.com.

● **Enter No. 80 at www.mwrf.com**

High-Current Pulsers

A FOUR-PAGE short-form catalog features nanosecond waveform electronics. High-current pulsers, high-speed pulsers, laser-diode drivers, converters, burst generators, function generators, power amplifiers (PAs), impulse generators, DC offset options, and general-purpose-interface-bus (GPIB) computer controls are offered. Medium-current pulsed-laser diode drivers, frequency dividers, burst generators, high-voltage pulse generators, high-voltage function generators and amplifiers, impulse generators, 100-ps rise-time pulsers, high-current laser-diode drivers, and general-purpose lab-pulse/delay generators are presented.
Avtech Electrosystems; (800) 265-6681, FAX: (800) 561-1970, e-mail: info@avtechpulse.com, Internet: www.avtechpulse.com.

● **Enter No. 81 at www.mwrf.com**

Coatings/Encapsulants

A SELECTOR GUIDE describes a line of solvent-free, light-curing conformal coatings and encapsulants. The brochure features processing information, as well as a selector guide listing five conformal coatings and four encapsulants. Features, benefits, and agency approvals which differentiate the line from traditional slower-curing conformal coatings are listed.
Dymax Corp.; (860) 482-1010, FAX: (860) 482-1308, e-mail: info@dymaxcorp.com, Internet: www.dymax.com.

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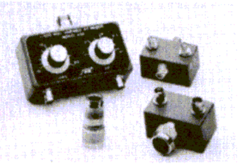
RETURN LOSS BRIDGES



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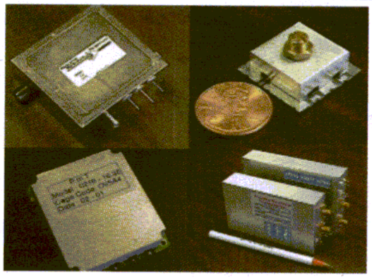

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Tuesday, Sept 25, 8:30 AM

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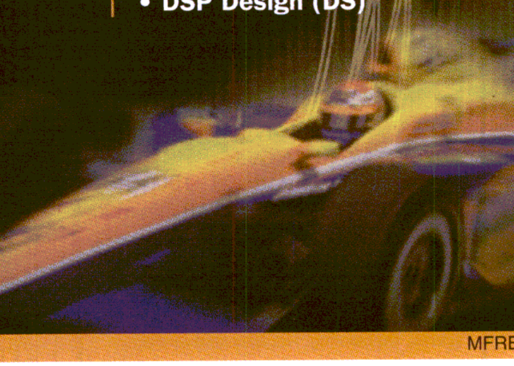

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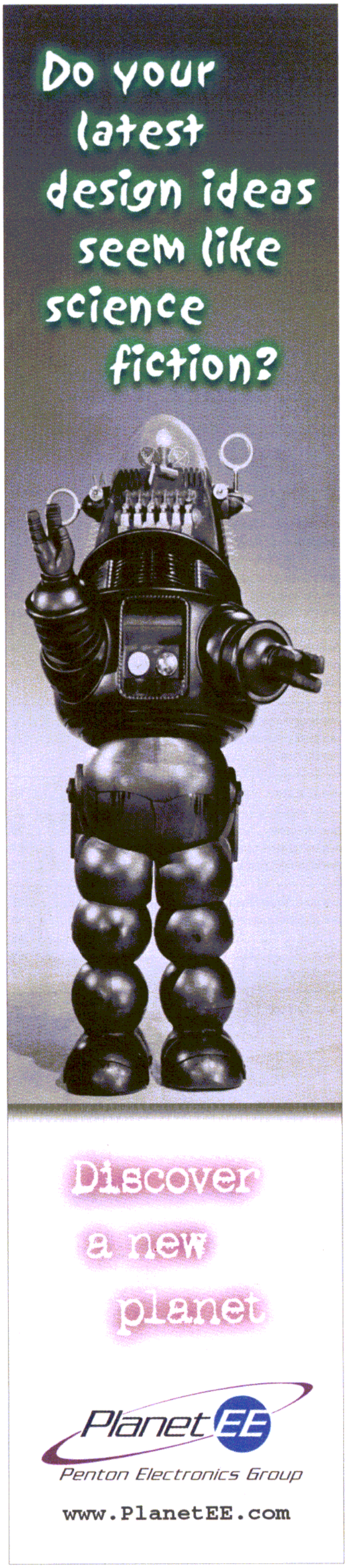
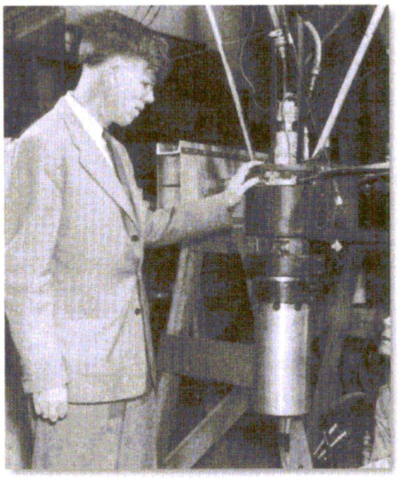


looking back



IN ITS 30TH ANNIVERSARY ISSUE 10 years ago, this magazine remembered such key moments as the invention of the klystron by the Varian brothers, Russell (left) and Sigurd (right), in 1953.

next month

Microwaves & RF August Editorial Preview

Issue Theme: 40th Anniversary/ Wireless Applications

News

In celebration of 40 years in publication, *Microwaves & RF* takes a fond look back over the events, technologies, and people who have shaped the high-frequency/high-speed industry since 1962. This will be an issue to cherish, loaded with interviews of key individuals at leading companies and classic photography to tell the story of an industry's moments of glory and failure during the past 40 years, as well as the magazine that has tried to capture those moments. There will also be a report on one of the longest success stories in this industry: Agilent Technologies/ Hewlett-Packard Co.

Design Features

In the August issue, the historical coverage will be backed by a strong lineup of technical articles, including features on designing high-frequency oscillators and simulating IM distortion in high-power amplifiers. Additional articles will examine a high-power LDMOS transistor for IFF avionics systems, techniques for the noncoherent detection of standardized FQPSK modulation, methods for making triggered measurements with a sampling power meter, how to design microstrip-coupled-line filters for WCDMA applications, as well as a review of SOS switch technology.

Product Technology

The Product Technology section will continue coverage of key product developments from the recent MTT-S conference and exhibition. Product reviews will cover an automated system for reliability testing of wideband RF devices, an automated assembly system that promises new levels of consistency in high-power RF transistors, and a line of low-noise fractional-N and integer phase-locked loops (PLLs). Additional product features will highlight a 100-W WCDMA PA for IM testing and a series of high-speed optical devices for OC-192 (10-Gb/s) systems.

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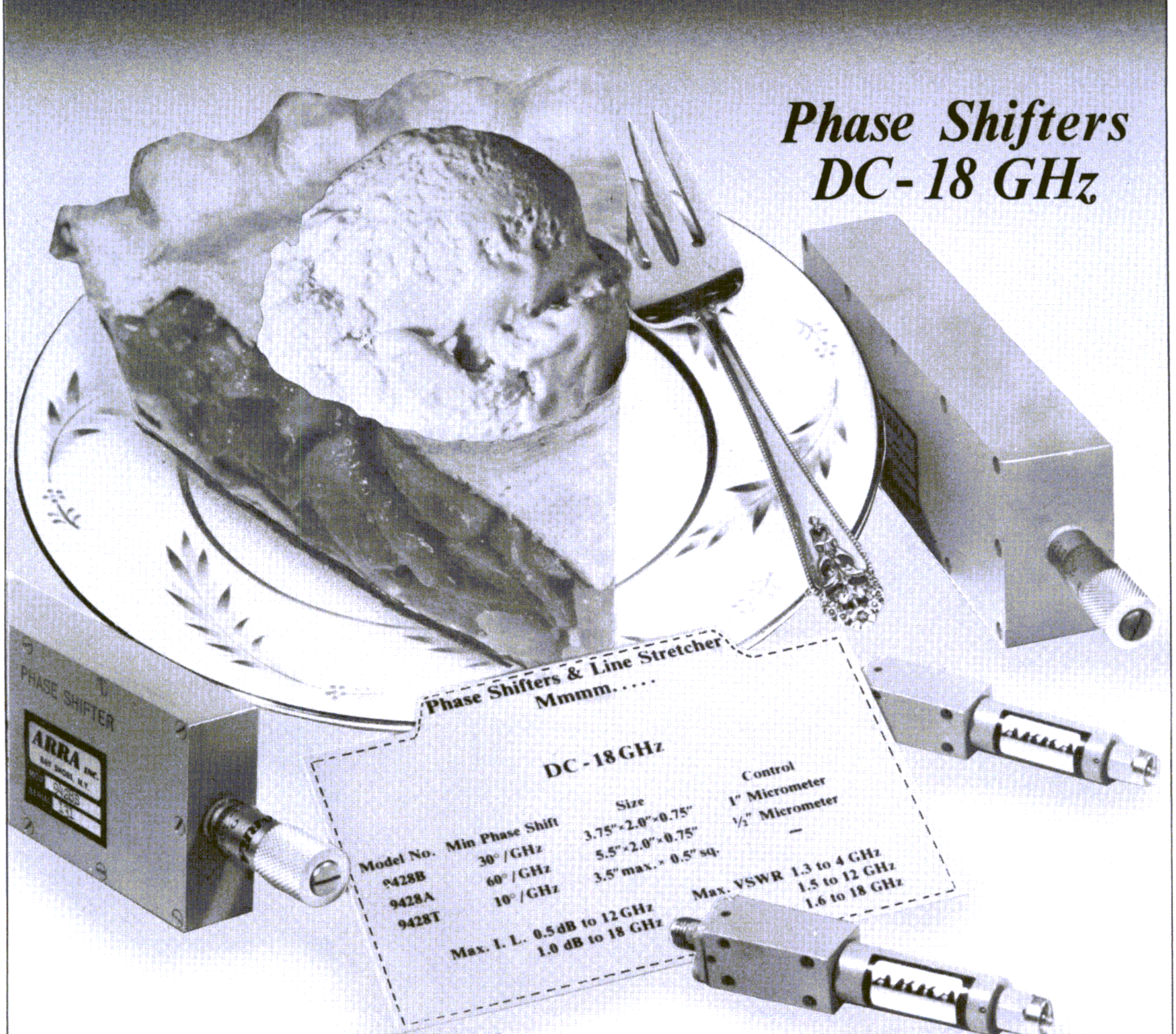

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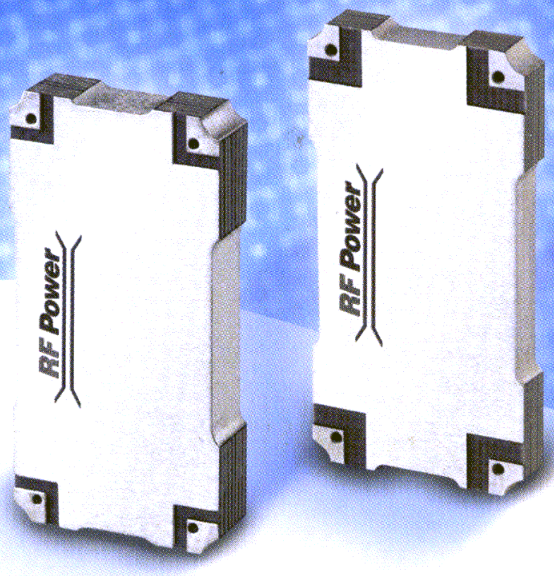

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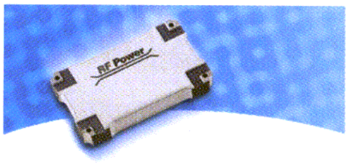
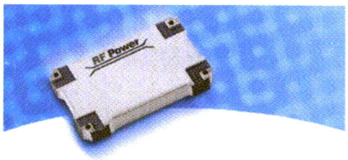
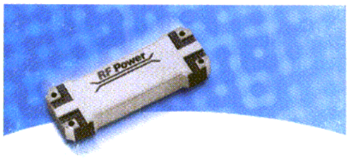


100 watt 90° hybrid SMD coupler — "A" case. Application for balanced amplifiers and signal distribution.



100 watt directional SMD coupler — "A" case. Application for frequency detection and can be used in most high power applications.



100 watt 90° hybrid SMD coupler — "E" case. Application for balanced amplifiers and signal distribution.

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